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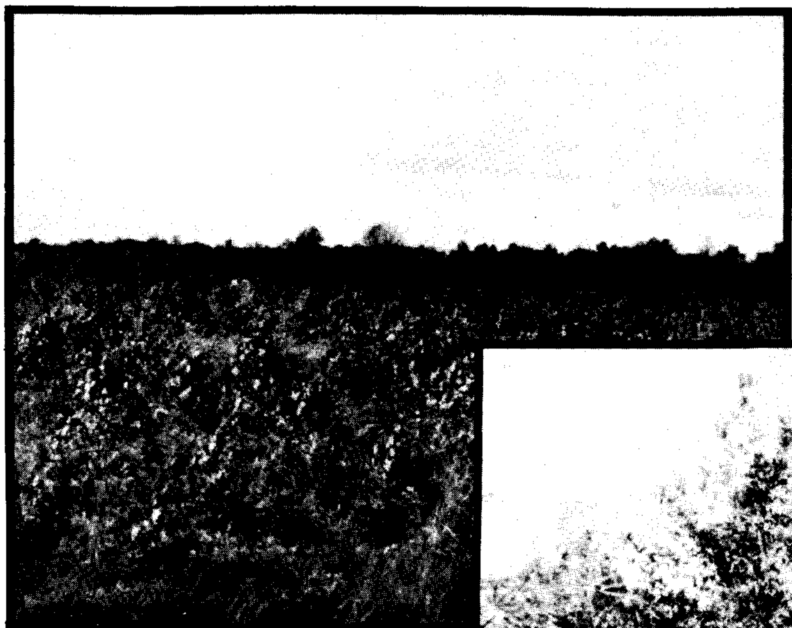
REESTABLISHMENT OF BOTTOMLAND HARDWOOD FORESTS ON DISTURBED SITES:

AN ANNOTATED BIBLIOGRAPHY



Fish and Wildlife Service
U.S. Department of the Interior

Cover photographs (courtesy of R.J. Haynes):

Upper: Three-year-old direct seeded oaks on old agricultural field in Panther Swamp National Wildlife Refuge, MS.

Lower: Ten-year-old mixed species plantation in Delta National Forest, MS.

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REESTABLISHMENT OF BOTTOMLAND HARDWOOD FORESTS ON DISTURBED SITES: AN ANNOTATED BIBLIOGRAPHY

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PREFACE

The U.S. Fish and Wildlife Service prepared this bibliography to assist those interested in the reestablishment and restoration of bottomland hardwood forests on previously disturbed sites such as abandoned farm land or surface-mined areas. Emphasis of the bibliography is on the Southeastern United States, although entries from other parts of the country are included whenever the authors believed these entries provided useful information. Annotated entries focus on applied restoration of bottomland hardwood ecosystems and "how to" papers concerning silvicultural practices.

Recognition of and interest in the importance and potential opportunities for the restoration of bottomland hardwood forest ecosystems have increased in recent years. Evidence of this includes specific language found in several recently enacted laws (e.g., Food Security Act of 1985, Emergency Wetlands Resources Act of 1986, Water Resource Development Act of 1986). With the increased interest in restoring bottomland hardwood forests, this bibliography should be both timely and useful to environmental planners, managers, and others concerned about this valuable natural resource.

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CONTENTS

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The authors gratefully acknowledge the assistance of Robert Johnson and Roger Krinard of the U.S. Forest Service, and Russ Lea of the North Carolina State Hardwood Cooperative, each of whom took the time to review drafts of this publication. Also Larry Moore, forester at Tensas National Wildlife Refuge, and Tim Wilkins, manager of the Yazoo National Wildlife Refuge Complex, provided the authors with valuable insight into the information needs of practitioners and would-be practitioners of bottomland hardwood restoration.

Although the three authors wrote this entire document, it would never have reached this final stage without the help of several members of the National Wetlands Research Center editorial staff. Daisy Singleton and Joyce Rodberg performed the difficult task of interpreting three different authors' writing and keyboarding the document. Rudy Krieger and Beth Vairin went through numerous iterations of editing this bibliography, Donna Glass helped design the cover, and Jan Landrum checked the accuracy of many of the citations.

INTRODUCTION

This bibliography was prepared to assist persons interested in the reestablishment of bottomland hardwood forests on previously disturbed sites, such as abandoned farm land or surface-mined areas. For the purpose of the bibliography, bottomland hardwood forests correspond with the "Needle-leaved Deciduous" and "Broad-leaved Deciduous" freshwater (Palustrine) forested wetlands described in the Wetlands Classification System used by the U.S. Fish and Wildlife Service (Cowardin et al. 1979). These forests occur primarily within the riverine floodplains of the Midwest and Southeastern United States.

The plant-species composition of bottomland hardwood forests is complex and varied, and is strongly dependent on the varying degrees of inundation (hydroperiod) during the growing season. Over 100 species of woody plants occur in these periodically flooded areas, and all exhibit some degree of adaptation for survival in soils which are inadequately drained and aerated. Commonly recognized species-zonation patterns range from the baldcypress (Taxodium distichum) and water tupelo (Nyssa aquatica) communities associated with longer periods of flooding, to the live oak (Quercus virginiana) and loblolly pine (Pinus taeda) communities on the highest floodplain areas. Depending upon the interaction of numerous ecological factors, many other plant-species associations may occur (see Eyre 1980; Clark and Benforado 1981).

From the mid-1950's through the mid-1970's, about 6 million acres of the Nation's freshwater forested wetlands were lost, principally through agricultural conversions. Although losses vary geographically, over 80% of the original forested wetlands in the Southeastern United States have been lost and about 25% of the remainder may be lost by 1995. In Illinois, about 98% of the bottomland forests have been lost (Harris et al. 1984; Tiner 1984).

Public concern over additional losses of bottomland forests has increased in recent years with better awareness of the many functions and values of these ecosystems (e.g., flood control and water quality protection, fish and wildlife habitat) and the realization of the magnitude of past and continuing losses (Greeson et al. 1978; MacDonald et al. 1979; Brinson et al. 1981; Conner and Day 1982; Wharton et al. 1982; Sather and Smith 1984; Tiner 1984; U.S. Congress 1984). Such changes in attitude have prompted more stringent consideration for the protection of these ecosystems through various regulatory and policy mechanisms (Federal Register 1977; U.S. Congress 1984, 1986a; Barton 1985). For example, Section 906 of the Water Resources Development Act of 1986 (Public Law 99-662) (U.S. Congress 1986b) states that future mitigation plans for Federal water projects should include specific plans to ensure that impacts to bottomland hardwood forests are mitigated in kind, to the extent possible. Also, the Council on Environmental Quality (1985) has stated that "the bottomland hardwoods in the Southeast are of such importance as wildlife habitats, and becoming so scarce, that the principle of full, in-kind replacement should override other considerations."

With increased regulatory emphasis on protection and conservation of wetlands, the need for additional information about the technological ability to reestablish forested wetlands on disturbed sites has also become more apparent. For example, evidence indicates that courts are now willing, and may prefer in some cases, to use information about the cost of carrying out specific vegetation reestablishment efforts in determining a fair assessment of damages in compensation issues (Anonymous 1983). In addition, the lack of a convincingly demonstrated technology has been, and is expected to continue to be, an important consideration in the approval/denial process for various surface-mining activities in forested wetlands (U.S. Bureau of Land Management et al. 1983; Haynes 1984; Haynes and Crabill 1984). The recent emphasis on wetland conservation as presented in the Food Security Act of 1985 (U.S. Congress 1985) may provide opportunities for reestablishment of bottomland hardwood forests on previously farmed and flood-prone areas regulated by the Farmers Home Administration (Office of Federal Register 1987).

Strategies for avoiding net losses of bottomland hardwood forests may include a preservation approach (e.g., land-use restrictions, easements, or land acquisition), or a compensation approach in which losses are replaced or an acceptable substitute provided (U.S. Fish and Wildlife Service 1981). This bibliography focuses on the compensation approach as it relates to the reestablishment of bottomland hardwood forest ecosystems on disturbed sites. Opportunities for such reestablishment occur when the initial loss or modification of the forest community is not permanent and reestablishment methods are technologically feasible. These opportunites may include (1) reestablishment on abandoned, "high-risk" farm lands in flood-prone areas, (2) reestablishment in national forests, wildlife refuges and management areas, flood-control projects, or public lands on which bottomland hardwood forest habitat serves management goals that are determined to be in the best public interest, and (3) reclamation of surface-mined lands.

SCOPE AND ARRANGEMENT

In the initial review of available published literature, over 400 scientific papers, government reports, M.S. and Ph.D. theses, and popular-journal articles were located dealing with one or more factors related to bottomland hardwood restoration. Most of these papers did not discuss restoration specifically, but covered related factors, such as hydrology and flooding effects, soils and nutrients, plant succession and competition, and plant propogation methods. Since time and available staff did not allow the annotation of all the papers that were found, only those references that were thought to contain information of direct value to persons involved in bottomland hardwood restoration were selected for annotation. These annotations form the main section of this report, and are arranged alphabetically by author.

In addition, the bibliography contains non-annotated entries grouped under specific subjects. These entries may be of value to persons requiring more in-depth treatments of specific species or silvicultural methods. Two appendixes are also included. Appendix A lists common and scientific names for bottomland hardwood species covered in this publication and Appendix B catalogues flooding, shade tolerances, and reproductive characteristics of selected bottomland hardwood forest species. Subject and species indexes are provided for cross-referencing of the annotated entries.

Although an attempt was made to include all appropriate citations through May 1988, some papers may have been omitted. We believe, however, that enough entries have been included to make this publication valuable to those involved in the important work of bottomland hardwood restoration.

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McKnight, J.S., D.D. Hook, O.G. Langdon, and R.S. Johnson. 1981. Occurrence, shade and flood tolerance and reproductive characteristics of the principal species of the southern bottomland forest. Pages 45-69 in J.R. Clark and J. Benforado, eds. Wetlands of bottomland hardwood forests. Elsevier Publishing Company, New York.

Sather, H.J., and R.D. Smith. 1984. An overview of major wetland functions and values. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS-84/18. 68 pp.

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Wharton, C.H., W.M. Kitchens, E.C. Pendleton, and T.W. Sipe. 1982, Ecology of bottomland hardwood swamps of the southeast: a community profile. U.S. Fish and Wildl. Serv. Biol. Serv. Program FWS/OBS-81/37. 134 pp.

ANNOTATED ENTRIES

Allen, H.H., and C.V. Klimas. 1986. Reservoir shoreline revegetation guidelines. U.S. Army Corps of Engineers, Environmental and Water Quality Operational Studies, Technical Report E-86-13. 87 pp.

Planning, site preparation, planting, postplanting operations and maintenance, and costs associated with revegetating reservoir shorelines with both herbaceous and woody species are covered. The two main elements of planning are site selection and the choice of plant species and materials. Important site factors to consider include water level fluctuations, bank morphometry, wave climate, animal depredation potential, and soil characteristics. In general, larger-than-average tree seedlings and species that leaf out late should be used to minimize damage from spring floods. Planting of four propagule types for woody vegetation--bare-root, balled-and-burlapped, and containerized seedlings and cuttings--is covered. There is a section on special establishment techniques in erodible environments in the planting chapter; detailed diagrams of most of the techniques are provided. Postplanting operations and maintenance are discussed only briefly. Monitoring is recommended in order to identify needs such as irrigation, fertilization, protection from animals, or cultivation.

Anderson, C.P., P.E. Pope, W.R. Byrnes, W.R. Chaney, and B.H. Bussler. 1983. Hardwood tree establishment in low plant cover on reclaimed mineland. Pages 158-170 in Proceedings of the third annual conference on better reclamation with trees. Purdue University, Terre Haute, IN.

The paper describes a comparison between a reclaimed surface-mined site in Sullivan County, IN, and an unmined reference site which was made to evaluate the effectiveness of hardwood seedling establishment, growth, and related factors. Black walnut and northern red oak seedlings (bare-root and containerized) were planted concurrently with a cover crop of fescue and red clover. Sites were disked, limed, and fertilized. Test areas were treated with herbicide to control ground cover and to assess the competitive effects of ground cover on seedling establishment and growth. After two growing seasons, red oak seedlings exhibited lower survival and less net height growth than black walnut seedlings. Individual container-produced seedlings survived better than bare-root seedlings. Herbicide use to reduce ground cover competition effectively improved black walnut survival and growth, but had no significant effect on red oak. Selected physical and chemical properties of the growth media are discussed.

Anonymous. 1984. Turning farmland into forests. Pages 10-11 in Woodlands for wildlife. Mississippi Department of Wildlife Conservation, Jackson, MS.

A large-scale, lo-year program to reforest nearly 1,000 acres of old farm fields on the Malmaison Wildlife Management Area in Mississippi is covered. Since 1981, about 100 acres/year have been direct seeded with oak acorns collected by wildlife area managers around Mississippi and shipped to Malmaison. Species planted include water, willow, and cherrybark oak. Sowing is done with a modified two-row John Deere planter; 40 acres/day can be planted. Researchers from the U.S. Forest Service Southern Forest Experiment Station in Stoneville, MS, are monitoring the results of the plantings. They report that germination and seedling survival appear to be adequate in most areas planted to date.

Anonymous. 1986. Results of oak direct seeding are promising. Tree Talk 7(2):9-11.

This article describes an oak direct-seeding project, which began in November 1981, on about 1,100 acres of old farmland in the Panther Swamp National Wildlife Refuge, in Yazoo County, MS. Species planted include water, willow, and Nuttall oak. Two planting machines were used: a modified antique "belly mount" cotton planter was used on heavy high-shrink Sharkey clay areas; and a converted John Deere Maxi-Merge 7,100 planter was used for planting unprepared ground that contained agricultural debris. Germination of willow oak began during April 1982 and Nuttall oak germination occurred from mid-May throughout the summer. Survival and germination were reported to be adequate. Although only oaks *were* planted, invader species, such as pecan, water hickory, persimmon, sugarberry, honeylocust, and green ash, are expected to be components of the mature stands and should enhance the overall value of the forest for wildlife.

Ashby, W.C., C.A. Kolar, and N.F. Rogers. 1980. Results of 30-year-old plantations on surface mines in the central states. Pages 99-107 in Proceedings of trees for reclamation. U.S. Forest Service General Technical Report NE-61, Broomall, PA.

This report indicates that after at least 30 years, 28 species of trees have been grown successfully on surface-mined lands in the Central States. Many of the previously planted stands were vigorously invaded by volunteer trees, as well as other plants and animals. The success of a species was affected by geographic location, type of rooting medium, and whether species were planted alone or interplanted. Species reviewed included maples, green ash, black walnut, sweetgum, tulip tree (yellow-poplar), pines, sycamore, cottonwood, oaks, and black locust. Green ash exhibited the highest survival rate of any species. Sweetgum showed both good growth and survival. Black walnut and tulip trees (yellow-poplar) were very site sensitive; growth and survival varied substantially due to variations in soil pH, drainage, and other factors. Sycamore and cottonwood yielded some of the largest trees although tree form was poor, and volunteer trees of these species often equaled or exceeded planted trees in size. Plantings of various oak species were successful in some locations; no planting failures are reported in the paper. Black locust showed rapid early growth before succumbing to the locust borer (Mesacvllene robiniae). Major invaders under established tree cover were elms, hackberry, and boxelder. Other important local invaders were black cherry, ashes, pin oak, shingle oak, and sassafras. Many areas exhibited a dense herbaceous layer. Common shrubs were dogwoods, grape, and sumac.

Ashby, W.C., W.G. Vogel, and C.A. Kolar. 1983. Use of nitrogen-fixing trees and shrubs in reclamation. Pages 110-118 in Proceedings of the third annual conference on better reclamation with trees. Purdue University, Terre Haute, IN.

The importance of nitrogen-fixing trees and shrubs to the establishment of other trees, and the advantages and disadvantages of using nitrogen-fixing species are discussed. Black locust, European alder, and autumn olive have been the most widely used species in mined-land reclamation. Nitrogen-fixing species can contribute to greatly accelerated growth and invasion of other trees. Black locust and European alder experience die-back and mortality after 5 or more years. The locust is often attacked by the locust borer, though some stands escape. Locust sprouts vigorously from roots and sprouts grow well if not shaded. The reasons for alder mortality are not well understood. As a disadvantage, locust and autumn olive often produce dense thickets that are difficult to move through for interplanting or underplanting other trees. Alder may exhibit excessive competitiveness on good sites; autumn olive may overtop young trees if planting densities are not carefully controlled, and the seeds can be widely distributed by birds to other areas where unwanted establishment may occur. The author notes that an extensive literature documenting the values of nitrogen-fixing species is available.

Baker, J.B. 1977. Tolerance of planted hardwoods to spring flooding. Southern Journal of Applied Forestry 1(3):23-25.

Inundation of cottonwood cuttings and seedlings (1-O stock) of sweetgum, water tupelo, American sycamore, and green ash were studied and detailed in this article. Cuttings and seedlings were planted on a Sharkey clay site near Stoneville, MS, in two consecutive years in 25-tree plots. After the trees had leafed out in May, 3 ft of water was pumped onto the plots, all trees were completely inundated for 4 weeks, and then the water was removed. Water tupelo, green ash, and sycamore were consistently most tolerant of spring flooding; survival was about 90%. Cottonwood was the least tolerant of flooding; an average of only 24% of the cuttings survived. All species except green ash lost their leaves each year during the flooding period. Average height growth for surviving seedlings one season after flooding was highest for cottonwood (3.7 ft), followed by green ash (2.8 ft), sycamore (2.4 ft), water tupelo (1.8 ft), and sweetgum (1.2 ft).

Baker, J.B., and W.M. Broadfoot. 1979. A practical field method of site evaluation for commercially important southern hardwoods. U.S. Forest Service General Technical Report SO-26, New Orleans, LA. 51 pp.

This report provides a method and guide for evaluating the suitability of sites for 14 hardwood species: cottonwood, green ash, pecan, sycamore, sweetgum, yellow-poplar, hackberry, sugarberry, cherrybark oak, Nuttall oak, Shumard oak, water oak, willow oak, and swamp chestnut oak. The method is based on the four most important determinants of hardwood growth: soil physical condition, moisture availability during the growing season, nutrient availability, and soil aeration. Based on the percentage of maximum tree growth attributable to each of these factors, a site quality rating (SQR) is assigned for best, medium, and poor conditions. The rating for each major factor is further divided according to the relative influences of soil-site properties; for instance, overall nutrient availability is assessed by rating geologic sources, past soil use, percent organic matter, depth of topsoil, soil age, and pH. All soil factors are tabulated and rated. Values from the table are summed to assess the site's suitability for a particular species. Estimates of potential productivity for cottonwood, sweetgum, and sycamore are also,given.

Bates, A.L., E. Pichard, and W.M. Dennis. 1978. Tree plantings--a diversified management tool for reservoir shorelines. Pages 190-194 in Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Proceedings of a symposium; U.S. Forest Service, Washington, DC.

This paper reports on studies that have been conducted since 1935 on shoreline plantings of water-tolerant tree species along periodically flooded or dewatered shoreline within the mainstream and tributary reservoirs of the Tennessee Valley Authority system. Baldcypress was determined to be the most desirable species for planting in the fluctuation zone of reservoirs because of its rapid growth rate and ability to withstand prolonged flooding even in the seedling stage. Recently, however, plantings of baldcypress have been detrimentally affected by high populations of beaver. Beaver populations along with competition from herbaceous species in the upper portion of the fluctuation zone seemed to be major limiting factors to successful plantings. Shoreline plantings of water-tolerant species provided the potential for shoreline stabilization, better habitat for desirable wildlife, a biological mosquito control method, replacement of wetlands lost in reservoir construction, and an aesthetically'pleasing shoreline landscape.

Bedinger, M.S. 1971. Forest species as indicators of flooding in the lower White River Valley, Arkansas. Pages C248-C253 in Geological survey research 1971. Chapter C. U.S. Geological Survey Professional Paper 750-C, Washington, DC.

This study indicates that flooding is the dominant environmental factor determining tree species distribution within the lower valley of the White River, AR. The relationship between flooding and tree species occurrence was sufficiently distinct to permit determination of flood characteristics at a given site by evaluation of forest-species composition. On sites flooded 29%-40% of the time, the dominant species were water hickory and overcup oak. On sites flooded 10%-21% of the time, species included Nuttall oak, willow oak, sweetgum, sugarberry, and American elm. Sites subject to flooding at intervals of from 2 to 8 years included southern red oak, shagbark hickory, and blackgum. The presence of blackjack oak marked areas not flooded in historic times.

Bonner, F.T. 1964. Seeding and planting southern hardwoods. Pages 28-40 in Proceedings of the Auburn University hardwood short course; Auburn, AL.

This paper summarizes the state of knowledge about southern hardwood seeding and planting as of 1964. A table is presented which includes planting information on cottonwood, sweetgum, green ash, sycamore, yellow-poplar, oaks, black walnut, water tupelo, and baldcypress. Information given includes recommended pruning length for roots, recommended top length, best root-collar diameter, adaptability to machine planting, response to fertilizer, usual first-year growth, suitability for wet sites, and susceptibility to animal and insect damage. In addition to the table, the paper includes sections on protection, cultivation and weed control, and direct seeding. Protection of sweetgum, oaks, green ash, and yellow-poplar seedlings can be difficult in old-field plantings, where they are susceptible to damage by rabbits and other rodents. No repellant is available yet for application to seedlings or cuttings. Protection from livestock and fire is essential for good results. Cultivation is very important in cottonwood plantations; cross-disking is the best method. Black walnut and sycamore also have been shown to benefit from weed control. Direct-seeding results to date have been erratic. Rodents have been responsible for most direct-seeding failures of oaks, and have also damaged black walnut seed. Some seeds, such as those of the red oaks and white ash, may remain dormant for a year or more after sowing.

Bonner, F.T. 1966. Survival and first-year growth of hardwoods planted in saturated soils. U.S. Forest Service Research Note SO-32, New Orleans, LA.

This study documents the growth of sycamore, sweetgum, and Nuttall oak in poorly-drained saturated soils typical of Mississippi River batture and slackwater clay areas (Commerce silt loam and Sharkey clay). One-year-old seedlings in pots of these two soils were kept under saturated conditions and monitored from February until August for various aspects of root and shoot growth. Timing of bud-break, initiation of height growth, and seedling survival were not influenced by either soil type or saturation. Saturation did decrease terminal, stem diameter, and root growth. At least 10 weeks of continuous saturation were required to produce large decreases in growth. Sycamore seedlings exhibited the best overall growth; however, terminal growth of the seedlings was more greatly impacted by saturation than in the other two species. Root growth was suppressed in Nuttall oak and sweetgum; sycamore roots grew twice as much in clay soil as in silt loam. Stress on the seedlings was also evident in measures of water balance, especially in silt loam.

Bonner, F.T. 1977. Handling and storage of hardwood seeds. Pages 145-152 in Proceedings of the second symposium on southeastern hardwoods; U.S. Forest Service State and Private Forestry, Atlanta, GA.

Techniques for seed storage and handling for a number of bottomland hardwood species are described. Sweetgum, sycamore, green ash, white ash, and yellow-poplar seeds should be stored dry (moisture content 6%-8%), as well as seeds from fruits or drupes (such as black cherry, dogwood, sugarberry, and water tupelo). A table of oven temperatures and drying times is given. Red and white oak acorns are stored moist; the seeds become non-viable when the moisture content drops to 25%-30%. Treatment of acorns for removal of insect larvae is not recommended. Dried seeds may be stored at temperatures of O-5 °C for long periods of time, or at higher temperatures if they are to be sowed during the next spring. Sweetgum, sycamore, yellow-poplar, green and white ash, and black cherry may be stored in this manner for up to 5 years. Water tupelo, shagbark hickory and cottonwood seeds can be stored for 2 to 3 years. Acorns should be maintained at 35%-45% moisture at temperatures between freezing and 2 °C in 4-mil-thick polyethylene bags to allow gas exchange. The more dormant the oak, the longer the acorn can be stored. Red oak acorns store much better than those of the white oak group. The control of moisture content in seeds is critical to avoid damage from lipid autooxidation (below 5% moisture), fungal growth (10%-18%), or heat from respiration (above 18%). Relative humidity in the storage area can be controlled, but is expensive; storing seeds in moisture-proof containers is more economical.

Bonner, F.T. 1984. Testing for seed quality in southern oaks. U.S. Forest Service Research Note SO-306. New Orleans, LA. 6 pp.

This paper describes various experiments on measurement of acorn vigor carried out at the Forestry Sciences Laboratory in Starkville, MS. A variety of techniques are discussed, including the standard laboratory germination test, cutting tests, radiography, tetrazolium staining (TZ test), germination rate tests (peak value (PV) and mean germination time (MGT)), and leached conductivity tests. In 1978, five lots of water oak, collected from 1975 to 1978 were randomly sampled for three types of tests: standard laboratory germination test, TZ, and the PV. These tests results were compared with indicators of seed and seedling performance in nursery beds. All tests clearly showed which lots were the best and the poorest quality. Results of the standard laboratory germination TZ tests appear to have been correlated with nursery germination and growth, but the number of lots precluded a definitive test. In 1982, multiple lots of white oak, water oak, and cherrybark oak were selected for the standard laboratory germination, TZ, PV, and MGT tests. The test results were again compared with several indicators of seedling performance in nursery beds and showed that TZ testing gave the best results for cherrybark oak, followed by the PV test; PV and MGT tests were best for water oak. No tests were significantly correlated with nursery germination of white oak. Seed vigor tests could not predict oak seedling performance after germination. Tetrazolium staining test results were significantly correlated with results of the standard laboratory germination test for white and cherrybark oaks, but not water oaks. In spite of the mixed results, seed quality testing is definitely recommended.

Bonner, F.T. 1986. Good seed quality -- how to obtain and keep it. Pages 31-36 <u>in</u> Northeastern area nurserymen's conference; State College, PA.

This paper contains recommendations for the collection, processing, storage, and planting of oak acorns and small "orthodox" seeds (such as sweetgum, sycamore, and yellow-poplar). Oak acorns need to be stored at higher moisture contents and thus are treated differently from the so-called orthodox species. Whereas the orthodox seeds can be dried to moisture contents of below 10%, white oak acorns will die at moisture contents below 35% and red oaks, below 25%. Both types of seed should be collected only when mature; many orthodox seeds reach maturity in the early fall, but, in general, collection should be delayed until the seeds have dried somewhat. Cut-and-float tests are recommended for acorns since weevil infestations may require additional collection efforts. Three key points for acorn storage are: (1) keep acorns moist; (2) keep them cool (1-3 °C); and (3) do not store them in airtight containers. Stratification periods are recommended for nine oak species. If stored correctly, orthodox seed may remain viable for at least 3 years. At best, white oak acorns should be stored only over one winter, and ideally should be planted the same fall they are collected. Most red oaks can be stored up to 3 years, but viability may fall 50% in this time The paper concludes with nine general considerations for assuring good seed 'quality.

Bonner, F.T., and J.A. Vozzo. 1985. Seed biology and technology of Quercus. U.S. Forest Service General Technical Report SO-66, New Orleans, LA. 21 pp.

This monograph is divided into two parts--current biological knowledge and handling and management of acorns. The first section briefly covers the taxonomy of the genus Quercus, and describes the anatomy, metabolism, dormancy, and predators of oak seeds in detail. The second section covers seed collection, cleaning and conditioning, treatment for insects, storage, stratification, and testing. All oaks belong to one of two subgenera of Quercus, which are generally referred to as red and white oaks. Both biological characteristics and some aspects of handling and management of acorns differ substantially, making the distinction between these groups important for planting operations. Acorns should be collected as soon as they are mature, which in the Midsouth is usually from late October to early November. Indicators of maturity are provided for both subgenera, and collection methods are covered briefly. It is very important to prevent excessive drying--loss of moisture should not exceed 5%. Treatment for insects should be done with caution since common treatment methods such as soaking in hot water and fumigating can also harm the acorns. Storage techniques vary between the subgenera. In general, white oaks cannot be successfully stored more than 4-6 months, and the best recommendation is to store them in the ground by planting them in the fall. A good method of storing red oaks is to keep them in polyethylene bags with a wall thickness of 4-10 mil at a temperature near, but above, freezing (1-3 °C). Recommended stratification periods for selected red oaks are provided, and some common test procedures are described.

Briscoe, C.B. 1957. Diameter growth and effects of flooding on certain bottomland forest trees. Ph.D. Dissertation. Duke University, Durham, NC.

This study covers tree diameter growth and the effects of flooding on seedlings of water tupelo, sweetgum, loblolly pine, laurel oak, baldcypress, water oak, northern red oak, cherrybark oak, slash pine, and swamp tupelo on seven types of physiographic sites in southeastern Georgia. Seedlings of water tupelo, swamp tupelo, northern red oak, cherrybark oak, and slash pine were treated to determine the effects of flooding on growth. All species tolerated up to 51 days of flooding and submersion (the longest period allowable in the experiment). Tolerance to flooding was related to the frequency of flooding at the different sites where the species were naturally found in southeastern Georgia. Submersion of the seedlings reduced growth more than just flooding the soil. Tolerance to flooding increased with age of the seedlings and decreased with the duration of the flooding event. Water temperature affected growth; seedling growth ceased at water temperatures of 41 °F and seedlings suffered some (reversible) damage at holding temperatures of 95 °F. Root growth was more reduced by flooding than was shoot growth. Slash pines suffered mortality after flooding due to a seed-borne fungus. Some swamp and water tupelo mortality due to insect larvae was observed.'

Briscoe, C.B. 1961. Germination of cherrybark and Nuttall oak acorns following flooding. Ecology 42(2):430-431.

The article details germination experiments on cherrybark and Nuttall oak acorns previously kept in cold, moist stratification for 4 months. The acorns were divided into 100-seed lots and four lots were randomly assigned to each of 10 treatments: no flooding; flooding in open-mesh bags in swamp water or tap water for 8, 18, and 34 days; and flooding in sealed containers of tap water for the three periods. Temperature of all the waters ranged from 37-40 °F. Following these treatments, acorns were germinated in wooden flats filled with vermiculite. The results indicated a significant interaction of species and flooding period, but no significant differences based on type of water used. Cherrybark oak germination was significantly lowered by the 34-day submersion period; germination averaged 44% after 8 days, 41% after 18 days, and 26% after 34 days. Nuttall oak was not affected by flooding period, and germination for all waters combined varied from 41% to 44%. There was some indication that the germination percentage for Nuttall oak was higher for large than for small acorns.

Briscoe, C.B. 1963. Rooting cuttings of cottonwood, willow, and sycamore. Journal of Forestry 61(1):51-53.

The report covers a study which took place on first bottoms of the Atchafalaya River in southern Louisiana. Cuttings of cottonwood, willow, and sycamore were obtained from natural stands and were collected each month from October 1957 through September 1958 (except August). Trees were cut near the ground with a machete; the basal 16-inch length was the butt-cut. The majority of the cuttings had a diameter inside bark of 0.3-0.8 inches, with a total range of 0.2-1.9 inches. Cuttings were set in a nursery bed on the same day they were collected; subsets of each species were removed each month to check for rooting. All species rooted every month, but November was the best month for cottonwood (92% of cuttings obtained and planted in November rooted) and March was best for willow and sycamore (100% of cuttings of both species rooted). October to December was the best period for rooting cottonwood, and January to March was best for sycamore, while willow did just as well on average in both periods. Butt-cuts rooted better (66% overall) than second-cuts (54%). Willow cuttings grew the fastest; sycamore grew the slowest. Butt-cuts of willow averaged 3.0 ft in height by the end of the study (about 5-6 months of growth), compared to 2.1 ft for cottonwood, and 1.4 ft for sycamore.

Broadfoot, W.M. 1976. Hardwood suitability for and properties of important Midsouth soils. U.S. Forest Service Research Paper SO-127, New Orleans, LA. 84 pp.

This document updates and expands previous information about important Midsouth soils and their suitability for hardwoods. Forty tables describe the properties of each soil, give management suggestions, and indicate occurrence, suitability, and productivity of various species. Of the 40 soils described, 16 are found primarily in the Southern Mississippi Valley Alluvium, 12 in the Silty Uplands, 9 in the Coastal Plains, and 3 in the Blackland Prairies.

Broadfoot, W.M., and R.M. Krinard. 1961. Growth of hardwood plantations on bottoms in loess areas. U.S. Forest Service Tree Planters' Notes 48:3-8.

This article, with pictures and detailed captions, briefly describes17- to 25-year-old hardwood plantations within the loess soil belt of Mississippi and Tennessee. A 17-year-old baldcypress plantation and a 6-year-old cottonwood plantation are included for comparison. All plantations were on abandoned farm land in stream bottoms or branch heads, and were established with 1-O nursery seedlings on a 6 by 6 ft spacing, (the cottonwood plantation was established from cuttings planted on a 9 by 9 ft spacing). In addition, two sweetgum plantations and one each of southern red oak, white oak, water oak, swamp chestnut oak, yellow-poplar, water tupelo, green ash, and river birch are depicted. At age 21, the three largest white oaks averaged 9.2 inches in dbh and 50 ft in height. After 25 years the yellow-poplar plantation had 61% survival and an average diameter of 5.3 inches. Data are also given for age, survival rate, dbh, and height for sweetgum, water oak, willow oak, swamp chestnut oak, green ash, cottonwood, and baldcypress. No data were collected for southern red oak or river birch.

Clewell, A.F. 1981. Vegetational restoration techniques on reclaimed phosphate strip mines in Florida. Wetlands 1:158-170.

A portion of this paper discusses preliminary results for forest reestablishment on phosphate-mined lands in Florida. Four methods of swamp restoration were evaluated: (1) planting of tree seedlings (primarily with bare roots rather than potted); (2) transplanting of saplings from natural swamps with a tree spade; (3) mulching, using topsoil from natural swamps; and (4) natural colonization. The author noted that the planting of tree seedlings promises the partial success of forest reestablishment; helps to overcome any inadequacy of natural seed sources; and is considered inexpensive, as long as a mechanical tree planter is used. It was pointed out that unavailability of preferred nursery stock could be a serious problem, Tree spading of saplings up to about 8 cm in diameter from natural swamps to adjacent reclaimed lands can be accomplished, though often with limited success. An operator can transplant about 200 trees a week using tree-spading equipment; however, the operation is limited to soils firm enough to support the equipment. Swamp mulching holds promise in special limited situations; mulching in strips or piles between planted trees is recommended. For colonization by natural invasion, an inverse correlation between distance from the nearest natural seed source (which in Florida is typically a riparian forest) and the number of species present was noted. Limitations to planting methodologies include cost, time requirements needed to satisfy regulatory requirements, and the self-sustaining capability of the species used.

Clewell, A.F. 1983. Riverine forest restoration efforts on reclaimed mines at Brewster Phosphates, central Florida. Pages 122-133 in D.J. Robertson, ed. Reclamation and the phosphate industry. Proceedings of a symposium; Clearwater Beach, FL; 26-28 January, 1983. Florida Institute of Phosphate Research, Bartow.

This paper provides the following summary statements about major forest reestablishment issues within the central Florida phosphate mining area: (1) Prescribed vegetational restoration activities are essential to restoring plant communities that closely resemble those of natural riverine forests; (2) Previous studies strongly suggest that natural dissemination of seeds can be incorporated into a restoration plan for a site bordering a natural seed source; (3) Bare-root seedlings can be used in restoration, but may not always yield satisfactory results; (4) Tree-spading may be advantageous in some situations. If tree-spading is attempted, irrigation may accelerate the recovery of the root system. Additional information regarding the value of tree-spading in forest restoration is needed; (5) Preliminary results from studies have suggested that direct seeding is possible for some species, but percentage of germination and survival may be low; (6) Mulching seems to be helpful in restoring riverine forests as long as high soil moisture is maintained; thus, irrigation may be required. Also, mulching (in this case topsoil spread about a foot in depth and obtained from a riverine forest) introduces many species of plants; (7) Weeds can result in severe competition for tree seedlings and young saplings, although weeds can provide shade and protection from wind. The author recommends additional study of several methods for partial weed control; (8) The author concludes that a riverine forest could be restored, but that successful restoration is dependent on using a combination of methods applicable to the specific situation.

Conner, W.H. 1988. Natural and artificial regeneration of baldcypress in the Barataria and Lake Verret Basins of Louisiana. Ph.D. Dissertation. Department of Forestry, Wildlife and Fisheries Science, Louisiana State University, Baton Rouge.

This dissertation covers natural regeneration occurring from 1982-87 and the results of four planting trials of baldcypress in southern Louisiana. Overall, natural regeneration was poor in both basins studied, and artificial regeneration was largely unsuccessful due to nutria depredation. In three of the trials, most unprotected seedlings planted in both logged and unlogged stands were quickly destroyed by nutria. Vexar plastic seedling protectors were tried, but at best only slowed the rate of seedling destruction slightly. Chicken wire fences were used to protect one planting, and survival ranged from 64% to 91%, compared to about 15% for the other trials. In the fourth trial, baldcypress seedlings were planted in a seasonally flooded crawfish pond in February and July for two consecutive years. February-planted seedlings that experienced one growing season before flooding had the best survival and growth. After 3 years, annual growth rates of February- and July-planted seedlings were similar.

Conner, W.H., and J.R. Toliver. 1987. Vexar seedling protectors did not reduce nutria damage to planted baldcypress seedlings. U.S. Forest Service Tree Planters' Notes 38(3):26-29.

This article covers the results of a baldcypress planting trial in southern Louisiana, which was designed totest the effectiveness of Vexar plastic seedling protectors as a deterrent to nutria depredation. Five areas of typical baldcypress-tupelo forest--four of which had been logged recently--were planted with l-year-old seedlings, and half the seedlings in each area were protected with Vexar seedling protectors. The seedling protectors slowed down the rate of destruction somewhat, but after 3 months, 85% of the protected seedlings and 87% of the unprotected seedlings had been destroyed by nutria.

Dickson, R.E., and T.C. Broyer. 1972. Effects of aeration, water supply, and nitrogen source on growth and development of tupelo gum and baldcypress. Ecology 53(4):626-634.

Three separate experiments on water tupelo and baldcypress are summarized. The experiments were designed to (1) compare the relative effects of saturated and unsaturated soil, aeration within the saturated soil, and nitrogen fertilizer source on growth; (2) determine the effects of aeration and water availability on internal plant moisture stress and growth; and (3) compare the effects of four soil-moisture regimes on internal moisture stress and growth. Seedlings were grown in 7-inch clay pots, with four or five seedlings per pot. Five soil-water regimes were more sensitive to anaerobic, saturated soil. Nitrogen fertilization produced more growth compared to no-nitrogen fertilization in saturated soil, but had no significant effect on seedlings in unsaturated soil. Urea produced more growth than nitrate for baldcypress, while the opposite was true for water tupelo. In general, baldcypress was more responsive to fertilization than water tupelo.

DuBarry, A.P., Jr. 1963. Germination of bottomland tree seed while immersed in water. Journal of Forestry 61(3):225-226.

The article details tests of seeds germinated in water. The seed of baldcypress, Carolina ash, green ash, buttonbush, sycamore, swamp tupelo, water tupelo, American elm, and sweetgum were subjected to 30 days of immersion in water to test germination. Testing was done in open-top, aluminum-foil containers filled with about 2 inches of tap water. Water temperature for the immersion treatments ranged from 75 to 90 "F, and constant, artificial light was maintained throughout the test period. Control groups consisted of seeds placed in sponge-type germinators, which kept seeds moist but not completely immersed. In addition, representative samples (whole seed) of each species were analyzed fornitrogen-free-extract (NFE) to evaluate its role in the germination process. Immersion in water was found to have a beneficial affect on soft-coated seeds with NFE contents of 25% or more. Only baldcypress and water tupelo failed to germinate after 30 days. Other species ranged from 21.5% germination (sweetgum) to 86.5% (buttonbush).

Erwin, K.L., G.R. Best, W.J. Dunn, and P.M. Wallace. 1985. Marsh and forested wetland reclamation of a central Florida phosphate mine. Wetlands 4:87-104.

This journal article discusses wetlands reestablishment on a 148-ha project site of phosphate-mined land in central Florida, of which 61 ha of wetlands and 87 ha of uplands were reclaimed in 1981-82. The wetlands were designed to create freshwater marsh, hardwood swamp, and open water. About 66,000 trees (12 wetland species) were planted. Tree seedling survival and condition as a function of type of seedling, season, and water depth were determined. Overall seedling mortality in the reclamation area was small. Carolina ash had the highest net survival (98%) and growth in height. Other species that exhibited high survival included red bay (90%), black gum (90%), sycamore (90%), Florida maple (86%), and sweet bay (83%). Following a very poor initial survival rate (58%), cypress seedlings gradually recovered through root stock sprouting to a 78% survival rate. Species with relatively low initial survival included Dahoon holly (56%), loblolly bay (44%), and laurel and live oaks (12%), although the data for the oaks may not be valid because of the small number of individuals in the sampling population. Growth rates of cypress seedlings were higher at low-water levels (e.g., <30 cm); it was recommended that water conditions during the first and second growing seasons should be kept low to increase height growth and survival. Competitive growth of some marsh plants (e.g., cattail, marsh willow) appeared to retard seedling growth and/or survival ability. However, if seedlings were successful in surviving the competition, their growth rate was high.

Ettinger, W., and C. Yuill. 1982. Sand and gravel pit reclamation in Louisiana: creation of wetlands habitats and its integration into adjacent undisturbed bayou. Pages 109-114 _in_ Wildlife values of gravel pits. Agricultural Experiment Station Miscellaneous Publication 17. University of Minnesota, St. Paul.

This paper describes a reclamation plan for an area surface mined for sand and gravel in Webster Parish, LA. The goal of the reclamation plan was to convert the barren unreclaimed site into a diverse assemblage of bottomland forest and shallow and deeper water habitat integrated into the Bayou Dorcheat and Lake Bistineau ecosystems. Important planning elements were water-level considerations, regrading and reshaping spoil, and revegetation. A limited program of tree planting was proposed. On areas above a typical yearly high-water mark, species to be planted included hickory, pecan, Shumard oak, and willow oak. Recommended species on seasonally flooded areas were green ash, overcup oak, water hickory, and water oak. As islands and emerging areas stabilize, baldcypress and other bottomland hardwoods were expected to colonize the site from adjacent undisturbed areas. As of 1982, the plan was being implemented but follow-up monitoring data were not available.

Finn, R.F. 1958. Ten years of strip-mined forestation research in Ohio. U.S. Forest Service Central States Forest Experiment Station Technical Paper 153. Columbus, OH. 38 pp.

This paper summarizes the results of 10 years of planting studies on coal strip-mined land in Ohio, and clearly shows that a variety of trees (including bottomland hardwood types) and forage plants can be successfully grown. Factors studied included species adaptation, mixed plantings, direct seeding and other planting methods, and the effect of grading on planted trees. Generally, poor results were obtained from direct seeding; grading retarded height growth of most planted trees.

Fletcher, S.W. 1986. Planning and evaluation techniques for replacement of complex stream and wetland drainage systems. Pages 195200 in Proceedings: new horizons for mined land reclamation. American Society for Surface Mining and Reclamation, Princeton, WV.

This paper describes a planning approach for replacing stream and wetland ecosystems on phosphate-mined lands in central Florida where existing systems are characterized, and hydrologic, soil, and vegetational profiles are developed for each community type and stream reach. Postmining plans are developed with consideration of premining conditions. The reclamation plan includes a series of iterative steps to allow reestablishment of each profile toward optimum configuration. Flow barriers, contouring, and other devices are designed to create proper hydroperiod conditions for each community type.

Fowells, H.A., editor. 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture Handbook No. 271. Washington, DC. 762 pp.

This handbook is an edited compendium of silvical papers on tree species of commercial importance. A total of 127 species are covered, including most of the major bottomland hardwood species. The information provided for each species includes habitat conditions (climate, soils and topography, and associated trees and shrubs), life history (reproduction and early growth, and sapling stage to maturity), and races and hybrids. (Authors' note: a new edition of this handbook is due to be published in 1988).

Francis, J.K. 1985. Bottomland hardwood fertilization--The Stoneville Experience. Pages 346-350 in Proceedings of the third biennial southern silvicultural research conference; Atlanta, GA.

Results of several fertilization studies with cottonwood and other bottomland hardwood species and species mixes are discussed. In eight studies, cottonwood plantations were fertilized with rates of nitrogen (NH_4NO_3) ranging from 0 to 600 lb/acre. In some of the studies, P and K were added to a treatment, and lime was included in one study. The best rates of N fertilizer were 150 and 300 lb/acre. Most of the responses to fertilizer occurred in the first year of the trials, and by the third year no further response was evident. Evidence indicates that the best time to fertilize cottonwood may be March; also, cottonwood may be more likely to respond to fertilizer at age 4 than at younger ages. Benefit was not derived from the addition of P, K, or lime in any of the trials. The most important cause of success or failure of a treatment was site history. Old field sites were much more responsive to fertilization than plantations established on sites recently cleared of forest. Plantations on medium-textured soils, such as Commerce or Convent, responded more to fertilization than plantations on Sharkey or Urbo soils. Results with other bottomland hardwoods were similar in most cases. Generally, the best response was obtained on old fields with N, or N and P. Responses in most cases were not high enough to justify the costs of fertilization given current forest-product prices. The author concluded that fertilization should be limited to special cases, which are not yet well-defined.

Fung, M.Y.P. 1986. Ground cover control with herbicides to enhance tree establishment on oil sands reclamation sites. Pages 179-182 in Proceedings of the symposium on new horizons for mined land and reclamation. American Society for Surface Mining and Reclamation, Princeton, WV.

The paper covers a common problem encountered during the initial phase of woody plant seeding establishment--competition by aggressive herbaceous vegetation for light, soil moisture, and nutrients. Ground vegetation must be properly managed to promote erosion control and soil improvement while minimizing any adverse impacts on tree seedlings. Two herbicides, amitrole and glyphosate, were evaluated for their ability to control herbaceous cover. Glyphosate, applied at 9.50 L/ha, was the more effective of the two in maintaining ground cover density at or below 55%. At this level, seedling survival and growth were significantly improved.

Gilbert, T., T. King, and B. Barnett. 1981. An assessment of wetland habitat establishment at a central Florida phosphate mine site. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-81/38. 96 pp.

This publication reports on a reclaimed mine restoration project initiated in 1978, and carried out by the Florida Game and Fish Commission in cooperation with the International Minerals and Chemical Corporation and the U.S. Fish and Wildlife Service. The 49-acre site, which was mined for phosphate in 1967-68, included both wetland and upland reestablishment areas, and was located in Polk County, FL, adjacent to the Peace River floodplain. In 1978, the area was graded, two water basins were created, and a meandering channel was constructed to connect the basins during periods of high water. Over 10,000 tree seedlings (16t species, including from 9 to 13 bottomland forest species) were planted in 26 test plots. Native herbaceous marsh plants were transplanted to the wetland portion of the site. Plantings, natural plant invasion, hydrology, water quality, and wildlife utilization were evaluated for about 18 months after site construction. The authors concluded that plantings can increase plant species diversity on new sites. Bareroot seedlings, larger transplanted trees, and freshwater marsh plants can be successfully introduced, but species selection and on-site planting location are primary factors to be considered. Natural invasion is also an important factor. The amount of plant subsidy that may be needed is dependent on (1) the distance of individual sites from a natural seed source, (2) the nearby natural plant community type, and (3) dispersal mechanisms. Generally, as the distance from the potential seed source increases, the amount of plant subsidy needed increases. Survival and growth data for each species are presented and reclamation methods are discussed. The authors concluded that although it was not yet possible to assess the long-term ecosystem aspects of wetland reestablishment for the study site, the short-term outlook was promising.

Gilmore, A.R., and W.R. Boggess. 1963. Effects of past agricultural practices on the survival and growth of planted trees. Pages 98-102 in Proceedings of the Soil Sciences Society.

This paper describes the results of a planting of four pine species (loblolly, shortleaf, red, and white) and three hardwood species (sycamore, green ash, and yellow-poplar) on a recently abandoned farm field in southern Illinois. The field had been used for 40 years to test crop rotations with various soil and fertilizer practices; the soil in the field was Wartrace series, which developed from loess. Treatments to portions of the field included the addition of manure, crop residues, limestone, and/or rock phosphate and no treatment controls. Pine seedlings (1-O for loblolly and shortleaf, and 2-O for white and red) were machine planted, and hardwood seedlings (all 1-O stock) were hand-planted in the spring. All pine species survived best on the untreated plots, or on those to which only crop residues had been returned. Survival was significantly less on plots that had been manured, and was drastically reduced on limed plots due to weed competition. Survival of sycamore and yellow-poplar was greatest on plots that had both lime and manure or crop residues. It was concluded that: (1) extreme caution should be used in planting pines on land that has been recently fertilized unless provision is made for weed control; (2) past fertility programs should be investigated; and (3) hardwoods require more fertile sites than pines.

Hansen, N.J., and A.L. McComb. 1955. Growth, form and survival of plantation-grown broadleaf and coniferous trees in southeast Iowa. Proceedings of the Iowa Academy of Science 62:109-124.

This paper summarizes the results of a survey (conducted during 1952-53) of old fields and degraded forest land in southern Iowa, planted with broadleaf and coniferous species during the years 1937-41. Typical bottomland forest species planted included green ash, American elm, cottonwood, and silver maple. Overall, data were collected for 17 broadleaf species and 10 coniferous species. After 12 - 15 years following planting, growth of deciduous species in general was poor on eroded, old-field sites and good on uncultivated and uneroded sites (primarily around abandoned farmsteads). Conclusions were limited because of absence of original planting records and data.

Harris, S.A., H. Bateman, and L. Savage. 1985. Sportsmen's paradise regained. Louisiana Conservationist 37(5):24-25.

This article describes a project to plant Nuttall oak, willow oak, overcup oak, baldcypress, and pecan on approximately 4,500 acres of recently purchased agricultural land. The tract joins the Russell Sage and Ouachita Wildlife Management Areas near Monroe, LA. A 5- to lo-year planting schedule has been planned, with approximately 900 acres/yr to be planted. During the first season, 870 acres of disked fields were planted using 114,000 seedlings and 6,000 lb of acorns. Some of the seedlings were hand-planted; a mechanical planter was used for the acorns. Prior to sowing, acorns were kept in cold storage or underground. As the first year's planting progressed, numerous study plots were established to monitor survival and growth of planted seedlings and acorns. The goal of the project is to reestablish a diverse bottomland hardwood forest on the tract. It is hoped that species such as water hickory, persimmon, elms, willow, sugarberry, and native understory plants will become established through natural regeneration.

Haynes, R.J. 1983. Natural vegetation development on a 43-year-old surface-mined site in Perry County, Illinois. Pages 457-466 in Symposium on surface mining, hydrology, sedimentation and reclamation. University of Kentucky at Lexington.

Natural revegetation was evaluated on a 43-year-old surface-mined site in southern Illinois. For the overstory, 16 species of trees were recorded. When compared with an adjacent oak-hickory climax forest on unmined land, the study site exhibited little similarity, but more closely resembled a southern floodplain or mesic forest type. American elm, cottonwood, sycamore, boxelder, and black cherry accounted for 77% of the importance value. Other volunteer species noted were shingle oak, red oak, pin oak, river birch, willow, hackberry, silver maple, dogwood, sassafras, and persimmon. The rate of succession on the site appeared to be suppressed. The primary factors thought to be limiting succession were competition from dense shrub and herbaceous vegetation and the lack of an available seed source for many heavy-seeded species (e.g., oaks and hickories) at an appropriate time for establishment.

Haynes, R.J., and F. Crabill. 1984. Reestablishment of a forested wetland on phosphate-mined land in central Florida. Pages 51-63 in Proceedings of the fourth annual conference on better reclamation with trees. Purdue University, West Lafayette, IN.

This paper describes the design and implementation of a cooperative forested wetland reestablishment effort involving the U.S. Fish and Wildlife Service, AMAX Chemical Corporation, and various State agencies on a 16-acre (6.5-ha), phosphate-mined site in central Florida (Hillsborough County). The revegetaation type (dominant overstory species included red maple, laurel and water oak, and loblolly bay), site preparation, mining activities, grading, topsoil storage, soil amendments, revegetation methods, experimental design, and monitoring are discussed. Study factors included topsoiling; mulching; use of potted plants, bare-root seedlings, and wildlings; natural invasion; control of plant competition; erosion control; establishment of vegetation islands; and evaluation of reclamation success. Data for categorical project costs were also summarized. About 90%-95% of the reclamation cost was estimated to be for earthmoving work involving heavy equipment. Project site revegetation was estimated to account for about 2%-3% of reclamation cost, whereas carrying out the short-term monitoring plan would require from 1% to 2%. Implementation of the revegetation and monitoring plan was scheduled to begin in 1985; thus, data were not available to evaluate the success of the project.

Haynes, R.J., and L. Moore. 1987. Reestablishment of bottomland hardwoods within national wildlife refuges in the southwest. Pages 95-103 in Increasing

our Wetland Resources. Proceedings of a conference; National Wildlife Federation-Corporate Conservation Council; Washington, DC.

Increased interest in the protection, conservation, and restoration of bottomland forests prompted the U.S. Fish and Wildlife Service (Southeast Region) in 1987 to review existing examples of bottomland hardwood reestablishment on National Wildlife Refuges in the Southeast. Efforts to reestablish bottomland hardwoods were identified on 12 refuges. Plantings ranged in size from less than 1 ha to about 405 ha and varied in age from about 1 to 19 years after planting. The majority of the planting sites were on periodically flooded land that had been previously farmed. Planting methods included direct seeding of acorns and transplanting seedlings, bothof which had distinct advantages and disadvantages. Efforts to control competing vegetation and use of amendments, such as fertilizer, were seldom used. The species most often planted were Nuttall oak, cherrybark oak, willow oak, water oak, and pecan, although several other species were planted. Natural regeneration relative to achieving a diversity of tree species was an important consideration at all sites, and additional evaluation of this issue is needed. Other limiting factors that may affect the success of plantings include (1) drought during the growing season or a late freeze following planting; (2) standing water and high temperature on sites with young seedlings; (3) flooding on sites where the species planted are not adapted either to the duration or the depth of flooding; (4) damage or destruction of seeds or seedlings by rodents, rabbits, or deer; and (5) poor seed viability or poor quality of nursery stock. The small data set evaluated indicated that with attentive management and control of limiting factors, reestablishment of a planned bottomland forest with desired tree species and high value for many species of wildlife should be possible within 40 to 60 years. Additional analysis of other demonstration sites and long-term data sets are needed.

Hosner, J.F. 1957. Effects of water upon the seed germination of bottomland trees. Forest Science 3(1):67-70.

This study was set up to determine the effects of water upon the seed germination of red maple, silver maple, American elm, sycamore, and cottonwood. Samples of 100 apparently sound seeds of each species were randomly selected and split into two lots of 50 seeds each. Half the lots were subjected to soaking in tapwater in a darkened root cellar at approximately 60 °F, for periods varying from 4 to 32 days. The other half were kept dry, but were otherwise subjected to the same treatments. Except for 16 red maple and 2 silver maple seeds, the seeds of elm, sycamore, red, and silver maple did not germinate while soaking in water, but germinated rapidly immediately after removal from water. Germination was consistently high for all periods of soaking. Cottonwood and willow seeds completed their germination in the water after 4 days of soaking and many seedlings were healthy after 32 days of soaking. It was concluded that flooding of bottomland hardwoods for up to 32 days does not seem to have an appreciable effect upon the germination of the six species tested (except possibly through indirect effects of siltation).

Hosner, J.F. 1958. The effects of complete inundation upon seedlings of six bottomland tree species. Ecology 39(2):371-373.

This article discusses the effects of complete inundation of seedlings of six bottomland hardwood tree species--cottonwood, willow, sweetgum, green ash, boxelder, and silver maple--for periods of 2, 4, 8, 16, and 32 days. Except for silver maple, which was grown from seed in a greenhouse, current-year seedlings were collected in the field, transplanted into two-and-a-half inch pots, and allowed to grow for 3 weeks before inundation. The seedlings were about 3 inches high when the test began, and all species except silver maple appeared healthy at the start. Inundation was in tanks placed outdoors in an area exposed to sunlight until 2:00 p.m.; water temperatures during the day ranged from 88-93 °F. The seedlings were kept covered with about a foot of pond water. All species, except silver maple, survived 8 days of complete inundation. After 16 days all replications of willow and green ash survived; two of three replications of sweetgum survived; one of three boxelder survived; no cottonwood survived. After 32 days, only willow survived. Recovery after inundation also varied. Willow and green ash recovered fastest, followed by cottonwood, sweetgum, and boxelder. The species, ranked according to their relative tolerances to complete inundation, were willow, green ash, sweetgum, boxelder, cottonwood, and silver maple.

Hosner, J.F. 1959. Survival, root, and shoot growth of six bottomland tree species following flooding. Journal of Forestry 59:927-928.

The article covers experiments in which green ash, cottonwood, hackberry, sycamore, cherrybark oak, and pin oak seedlings were tested for survival, and root and shoot growth following flooding. Seedlings were immersed for 38 days in enough tapwater to cover the surface of the soil to a depth of about one quarter of an inch, after which they were removed and measured. The four most vigorous appearing seedlings of each species were then kept for another 60 days in moist but well-drained soil, and remeasured. The results showed pronounced differences among the six species in their ability to adjust to changing soil moisture conditions. Cottonwood, sycamore, and ash seedlings rapidly developed adventitious root systems after flooding, but the oaks and hackberry did not. The hackberry seedlings all appeared dead within 3 weeks. The oaks survived, but their roots only weakly recovered after flooding, and no new leaf or shoot growth occurred in the 60-day post-flooding period. Shoot growth recovery was rapid for cottonwood and green ash, but much delayed for sycamore.

Hosner, J.F., and S.G. Boyce. 1962. Tolerance to water saturated soil of various bottomland hardwoods. Forest Science 8(2):180-186.

This study reports on current-year seedlings of 17 bottomland hardwood species native to southern Illinois which were tested for tolerance to water saturated soil. Potted seedlings were subjected to completely saturated soils for 15-, 30-, and 60-day periods by placing pots into tanks filled with tap water to a level of about 1 inch above the soil line. Observations were made on mortality, height growth, development of the established root system, and the formation of adventitious roots. Mortality occurred among seedlings of five species--cherrybark oak, Shumard oak, sugarberry, cottonwood, and American elm. Cherrybark oak was the only species to experience mortality after 15 days, and had the highest mortality after 60 days (86.7%). The tops of all seedlings of the other 12 species were alive after 60 days of complete soil saturation. Nine species actually had faster height growth in soil saturated for 60 days than in unsaturated controls; in order of greatest to least difference, these species were green ash, water tupelo, pumpkin ash, pin oak, willow, sugarberry, cottonwood, silver maple, and boxelder. Species whose height growth was adversely affected were Shumard oak, cherrybark oak, red maple, sycamore, hackberry, sweetgum, willow oak, and elm. The roots of water tupelo, willow, pumpkin ash, and green ash continued to grow under completely saturated soil conditions; the remaining species did not have any actively growing root tips after 30 days, but some (American elm, cottonwood, sycamore, silver maple, and red maple) had many adventitious roots.

Howells, R.G. 1986. Guide to techniques for establishing woody and herbaceous vegetation in the fluctuation zones of Texas reservoirs. Texas Parks and Wildlife Department, Austin, TX.

This publication provides guidance on several aspects of woody and herbaceous plant establishment, including propagule types, collection and storage of propagules, site selection and preparation, planting techniques, protection of plantings, post-planting maintenance, and monitoring. Emphasis is placed on the establishment of selected species which were indentified as suitable for establishment in the fluctuating zones. The woody species selected are willow, cottonwood, buttonbush, swamp privet, sugarberry, baldcypress, and water tupelo. Relevant characteristics of each of these species are described; species are also frequently referred to throughout the chapters on the aspects of establishment.

Hunt, R., J.L. Byford, and J.L. Buckner. 1976. Hardwood regeneration and white-tailed deer compatibility on a large clearcut in an Alabama flood plain. Southlands Experiment Forest Technical Note No. 37. Woodlands Department, Southern Kraft Division, International Paper Company, Bainbridge, GA.

The primary objectives of this study were to determine if large clearcuts in bottomland hardwoods would naturally regenerate with desirable species and if detrimental deer browsing would occur. Two large clearcuts (435 and 490 acres), in an area about 35 mi north of Mobile, AL, were chosen for study. Both clearcuts are subject to annual inundation from overflow of the Mobile River for a 2- to 5-month period during winter and spring. After five growing seasons, both clearcut areas had adequate natural regeneration (1,769 and 1,822 stems/acre). Initial large numbers of deer (about 1/20 acres) did not harm the natural hardwood regeneration. At age 5, cottonwood, sycamore, and green ash dominated the first area; although they composed only 13% of the total number of trees, they ranged from 16-20 ft in average height. Red oaks and sugarberry made up 76% of the trees in the second compartment, and averaged 2-5 ft in height. The differences in regeneration of the two clearcuts were probably the result of different stand histories: the second compartment had been high-graded several years before installation of the study; the first compartment was clearcut in 1968 and the second in 1969; and different amounts of seed were transported to the sites by floodwaters.

Johnson, R.L. 1979. Adequate oak regeneration--a problem without a solution? Pages 59-65 in Management and utilization of oak. Proceedings of the seventh annual hardwood symposium of the Hardwood Research Council; Cashiers, NC.

Two possible solutions to the problem of inadequate oak regeneration in existing southern hardwood stands are discussed: natural and artificial regeneration. The best opportunity for increasing the natural oak component of existing stands is through proper handling of natural oak reproduction. This may involve light thinning or shelterwood cuts and/or removal of competing shade-tolerant mid-story trees. In the section on artificial regeneration, both direct seeding and planting seedlings are discussed. Direct seeding has often been unsuccessful in the past, primarily due to rodent damage. Placing acorns in protective hardware-cloth cylinders has proved to be somewhat effective, but is too expensive to be used much in practice. Studies at Stoneville, MS, show that direct sowing in cleared areas 3 acres or larger results in much less rodent damage than smaller openings or underplanting acorns in forests. Planted seedlings, with weed control by straddle-cultivation and disking, resulted in several successful oak plots ranging from 20 to 200 acres. Best results were obtained with seedlings greater than 24 inches tall and at least 0.3 inches at the root collar. Planted oaks generally averaged a foot or two in annual height growth for the first 1 or 2 years in the field, and increased to 3 or 4 ft/year in the third and fourth years of growth. Care must be taken when planting old fields or cleared sites where desired oak species are absent. Also, in some cases soil pH can be a critical consideration. For example, an experimental planting of Nuttall, cherrybark, and water oaks failed on a moist, fertile bottomland soil with a relatively high pH (7.5), presumably because the seedlings were unable to extract iron from the soil. Experience indicates that oaks normally found in areas inundated for extended periods can be successfully planted on higher, better-drained sites, but the opposite is not true.

Johnson, R.L. 1981a. Oak seeding - it can work. Southern Journal of Applied Forestry 5(1):28-33.

The article describes a direct-seeding trial in which nearly 20,000 acorns of Nuttall oak were sown in Sharkey clay soil in the Delta Experimental Forest near Stoneville, MS, to compare field germination of acorns at different presowing treatments, different sowing times, and different sowing depths. Acorns were collected in November 1968 from 14 parent trees and were placed in dry storage at 35-40 °F. Float tests were used to eliminate unsound acorns, and sound acorns were randomly assigned one of three stratification treatments: January sowing in the field; 3 months additional storage at 35-40 °F in moist sand covered with burlap; or 3 months additional storage at 35-40 °F in sealed polyethylene bags, 4-mils thick. Acorns stratified in these three treatments were then planted at 1-, 2-, and 4-inch sowing depths. Acorns in the second two stratification methods were sown during the first 2 weeks of May 1969 at a spacing of 5 by 10 ft with 4 acorns planted in each spot. Rodents destroyed all acorns planted in undisturbed forest sites within a week, and damaged nearly three-fourths of the acorns sown in 40 by 90 ft cleared strips. Sowing in these two areas was considered a failure and not monitored further. Less than 5% of the acorns sown in 350 by 350 ft cleared plots were disturbed by rodents. Acorns sown 1 inch deep in January germinated significantly better (55% of total sown) than any of the other eight combinations of stratification treatments and sowing depths.

Johnson, R.L. 1981b. Wetland silvicultural systems. Pages 63-79 in Proceedings of the thirtieth annual forestry symposium, Louisiana State University, Baton Rouge.

Silvicultural systems are discussed that are applicable to one or more species groups occurring on lowland sites in the Midsouth. The species groups are cottonwood, elm, sycamore, pecan, sugarberry, sweetgum, water oaks, red oaks, white oaks, mixed species; black willow; overcup oak, water hickory; elm-ash-sugarberry; and cypress-water tupelo. Each of these species groups is related to the type of physiographic site on which it is generally found. Cottonwood, black willow, overcup oak-water hickory, and cypress-water tupelo are best managed as even-aged species groups, while the other groups can be managed as even-aged or uneven-aged stands. Five regeneration systems are recognized for lowland hardwood forests and are briefly discussed, including single tree selection, group selection, seed tree, shelterwood, and clearcuts. A table summarizes the expected results of applying some of these generation systems to the species groups.

Johnson, R.L. 1983. Nuttall oak direct seedings still successful after 11 years. U.S. Forest Service Research Note SO-301, New Orleans, LA. 3 pp.

This technical note reports on a successful Nuttall oak direct-seeding experiment on a Sharkey clay site in the Delta Experimental Forest, near Stoneville, MS. Forty-five hundred acorns were sown on an intensively-prepared site in April, 1971. Sowing treatments included hand-planting and machine planting at depths of 2, 4, and 6 inches. The first seedlings appeared in early May from acorns sown 2-inches deep; seedlings from 6-inch-deep acorns appeared about 2 weeks later. Some earlier direct-seeding trials had failed due to rodent depredation of acorns, but in this case, less than 10% of the acorns were believed to have been destoyed by rodents. Field germination ranged from 27% to 41%; better germination was obtained with hand sowing (versus machine) and 2-inch (versus deeper) sowing depths. Overall, 96% of the seedlings alive after one growing season were still alive after 11 years, and no significant difference in survival existed among treatments. The largest Nuttall oaks were 3-4 inches dbh and 20-25 ft tall. About one-third of the 11-year-old trees were overtopped partially or completely. Naturally invading tree species were green ash, cottonwood, sugarberry, sweetgum, American elm, persimmon, and water hickory. Except for two 6-inch-dbh, 35-foot-tall cottonwoods, however, the largest non-oaks were about the same size as the largest Nuttalls.

Johnson, R.L., and R.C. Biesterfeldt. 1970. Forestation of hardwoods. Forest Farmer November: 15, 36-38.

Forestation of hardwoods by both natural regeneration and planting is discussed. In general, successful plantations of hardwoods depend on the forester's ability to choose the proper sites, species, and tree spacings. Sites usually cannot be easily modified to suit a particular species. Green ash, sweetgum, Nuttall and willow oak, sycamore, and cottonwood are generally suitable for slackwater sites. In areas where water stands for much of the growing season, green ash or Nuttall oak should be planted; in slightly drier areas, cottonwood and sycamore are recommended because of their rapid growth. Spacing is the least important of the three initial choices, but becomes more important as the stand develops. A key consideration when deciding on spacing is the amount of weed control planned. If little or no weed control is planned, spacing should be as close as practical (no more than 6 by 6 ft); spacing should be 12 by 12 ft or wider if complete weed control is exercised. Weed control is especially critical in cottonwood plantations, but produces better results in all species. Weed control ideally should be carried out until the tree crowns close and shade-out competition. Based on the limited data available, projections of tree size at age 10 for suitable sites are cottonwood, 60-80 ft in height and 6-8 inches dbh; sweetgum, 20-30 ft in height and 2-3 inches dbh; and yellow-poplar and sycamore, 50-60 ft tall and 5-6 inches dbh.

Johnson, R.L., and R.M. Krinard. 1985a. Oak seeding on an adverse site. U.S. Forest Service Research Note SO-319, 4 pp.

The study reports on Nuttall and water oak acorns sown on an old-field site of Sharkey clay soil near Greenville, MS. The field had been farmed for 15-20 years, and was typical of many marginal crop production sites in the region. Acorns were collected from three Nuttall and three water oaks; the parent trees were selected because they produced different-sized acorns. Acorns were float-tested, and non-floaters were stored at 35 to 40 °F for about 3 months in polyethylene bags. Treatments were combinations of parent trees (i.e. different acorn sizes) and sowing depths (2, 4, and 6 inches). Acorns were hand-sown on a 4 by 10 ft spacing, with three acorns planted per hole. Twice during the first year, the strips between each row were mowed. Seedling survival after one growing season was 55% for Nuttall oak and 35% for water oak. Large water oak acorns did very poorly; if they are excluded, average seedling survival was 49%. Over 90% of Nuttall oak acorns germinated by late July; most water oak acorns germinated in August and September. Sowing depth of both species affected germination, which declined with depth; the best germination depth was 2 inches. By the end of the first growing season, the tallest seedling per spot averaged 0.56 ft for Nuttall oak and 0.26 ft for water oak.

Johnson, R.L., and R.M. Krinard. 1985b. Regeneration of oaks by direct seeding. Pages 56-65 in Proceedings of the third symposium of southeastern hardwoods, Dothan, AL. U.S. Forest Service Southern Forest Experiment Station, New Orleans, LA.

Results of oak seeding research at Stoneville, MS, and a number of commercial seedings are given. Research sites included eight in the Mississippi Delta, two in minor stream bottoms, and five in silty uplands. Commercial sites were in the Mississippi Delta and silty uplands. Topics covered included animal damage, species, site selection, seed collection and storage, time of seeding, depth of seeding, method of sowing, spacing, weed control, survival and growth, and the future of oak seeding. It was found that site-prepared clearings of two acres or more and old agricultural fields have less rodent damage than smaller clearings or plantings under a full forest canopy. Nuttall oak has consistently yielded the best results of the species tried to date, and, in general, red oaks germinated better in the field than white oaks. Timing and duration of flooding and soil type are key considerations in site selection. Seed should be collected soon after falling and placed in cold storage immediately. Acorns can be sown at any time of year, but June or July is best in flood-prone areas after the water has receded. Trials have been conducted with three planting depths: 2, 4, and 6 inches; all can be successful, but a P-inch depth generally yields the best results. Spacing can vary, but should leave about 30 ft^2/acorn. Intensive weed control by disking has been shown to improve early height and diameter growth.

Johnson, R.L., and R.M Krinard. 1987. Direct seeding of southern oaks--a progress report. Pages 10-16 in Proceedings of the fifteenth annual hardwood symposium. Hardwood Research Council, Memphis, TN.

This paper summarizes some of the experience gained since 1981 in the direct seeding of over 4,000 acres of land in the South. Most of these plantings have been on abandoned farm lands in floodplains. The report includes information on associated costs, seed handling, planting methods, survival, growth, and competition. Sowing in the winter generally produces the best results, although satisfactory results have also been obtained from summer plantings, and, in the case of Nuttall oak, from plantings done every month of the year. One possible advantage of sowing in winter is that acorns sown soon after collection (which is done in fall) seem to be damaged less by rodents. Although it is best to plant acorns as soon after collection as possible, the irregular occurrence of good seed crops may necessitate storing extra acorns in good years to offset future bad years. The cost of collecting acorns was estimated at $20.00/acre, and of storage, $0.50-$2.00/acre. Planting in large open fields has generally been done using modified soybean planters. Planting is easier and produces better results when the site has been well prepared. Burning, disking or cross-disking, and soil pulverizing may be necessary, depending on the condition of the field. Smaller fields or openings in forests have been successfully planted by hand. Most land managers do not attempt to control weeds in old field plantings, but in a few research trials, bushhogging between rows appears to have improved seedling survival and growth. Total costs of establishment by direct seeding, including acorns, labor, and site preparation, may range from $12.00-50.00/acre. The paper concludes with a section on direct-seeding failure, which has been attributed to flooding, droughts, residual herbicides, poor quality acorns, and animal damage.

Johnson, R.L., and T.L. Price. 1959. Resume of 20 years of hardwood management on the Delta Purchase Unit. Final Report. U.S. Forest Service Southern Forest Experiment Station, New Orleans, LA.

Hardwood research on the Delta Purchase Unit, located near Rolling Fork, MS, is summarized. The report begins with a detailed description of the Unit, including physiographic features, occurrence of wildfires and floods, climatic conditions, vegetative features, and natural areas. Discussion of the forest management and research program is divided into four sections: (1) fire, (2) cutting program, (3) cull-and-weed tree deadening, and (4) planting. In 1945-58, there were 35 different attempts at planting, totaling approximately 700,000 trees. Green ash, sweetgum, cottonwood, baldcypress, Nuttall oak, and sycamore were planted. Most of the planting stock was 1-0 seedlings grown from locally collected seed, but cottonwood was the major exception; cuttings were used for this species. In a few cases, transplanted wild seedlings (wildlings) were used. Most planting was done during February and March, and planting was done by hand under three conditions: (1) areas infested with heavy buckvine; (2) stand openings created by logging; and (3) stand conversion areas. Overall, 80% of the green ash, 73% of the baldcypress, 41% of the cottonwood, and 10% of the sweetgum plantings were judged successful. All sycamore, Nuttall oak seedlings and wildlings, and green ash plantings were failures. Based on average growth of all plantations, cottonwood grew 3.0 ft/year, green ash 1.5 ft, and baldcypress and sweetgum, 1.2 ft. The paper discusses in detail species results by physiographic site and the three planting site conditions mentioned above.

Jones, L. 1962. Recommendations for successful storage of tree seed. U.S. Forest Service Tree Planters' Notes 55:9-20.

This article provides recommendations on moisture content, temperature and other seed storage considerations for a large number of species and species groups, including most bottomland hardwoods. In storing tree seed the following must be considered: type of container, seed moisture content, storage temperature and facilities, and seed condition. Several studies have shown that seed moisture content rises during closed storage, and it is suggested that seed should be dried down to the lowest recommended level and moisture content checked periodically, especially if the seed is to be stored longer than 1 year. Storage temperature should be held constant. Some species, such as oaks, will benefit from treatment for insects prior to storage, otherwise insects may become active again immediately upon removal of the seeds from storage.

Kaszkurewicz, A., and P.Y. Burns. 1960. Growth of planted hardwoods on a bottomland terrace site in south Louisiana. Louisiana State University Forestry Note No. 37. Louisiana State University, Baton Rouge. 2 pp.

Growth of a 30-year-old plantation of Nuttall oak, water oak, live oak, swamp chestnut oak, and yellow-poplar is described. The plantation is located on the Louisiana State University campus in Baton Rouge, and is described as follows: a Mississippi River terrace (not subject to flooding); mean annual temperature, 68 °F; average annual rainfall, 59 inches; soil, Lintonia silt loam (well-drained, 1%-2% slope, pH 5.8). The site was a former agricultural field that was covered with weeds and brush when the trees were planted. Planting was done by hand with 1-0 stock at about 10 by 10 ft spacing. About 5 years after planting, the trees were released from weed and brush competition. After 30 years, except for Nuttall oak, the trees were generally healthy. Nuttall oak is not native to the site, which may be too dry; most of the Nuttall oaks had dying branches and tops, rough bark with insect holes, and a marked decrease in diameter growth during the last 5 years. Yellow-poplar had the greatest average diameter growth (14.7 inches) and height growth (82 ft). Nuttall oak dbh and height averaged 11.9 inches and 72 ft. Corresponding figures for the other species were water oak, 11.7 inches and 75 ft; live oak, 10.2 inches and 66 ft; and swamp chestnut oak, 8.5 inches and 72 ft. Sweetgum was a significant invader species, averaging 9.6 inches in dbh and 75 ft in height.

Kellison, R.C., D.J. Frederick, and W.E. Gardner. 1981. A guide for regenerating and managing natural stands of southern hardwoods. North Carolina Agricultural Research Service Bulletin 463. 23 pp.

This bulletin is primarily a guide for obtaining good natural regeneration from existing stands of southern hardwoods, but it contains some information that may aid in species selection for unforested sites and management of young stands. The guide has four major sections: (1) planning for regeneration; (2) regeneration systems; (3) species succession and stand development; and (4) species composition and stocking control. Natural regeneration topics briefly discussed are stand conditions, site types, when to regenerate, response of species to release, and growth habits of seedling and coppice regeneration. Regeneration systems covered are single-tree selection, group selection, shelterwood, tree, and clearcut. A description of naturally-occurring succession on various site types and shade-tolerant undesired species is given. The last section discusses management of 1- to 25-year-old stands from an economically oriented timber production perspective.

Kennedy, H.E., Jr. 1984. Hardwood growth and foliar nutrient concentrations best in clean cultivation treatments. Forest Ecology and Management 8:117-126.

This article presents data on nine hardwood species planted on a 4-ha commerce silt loam site at Huntington Point, about 24 km north of Greenville, MS. The site had been recently cleared of a natural mixed hardwood stand and prepared for planting by shearing, root raking, and disking. Twenty-four l-year-old seedlings or cottonwood cuttings were planted in February at 3 by 3 m spacing in each plot. The species planted were cottonwood, sycamore, Nuttall oak, cherrybark oak, water oak, pecan, green ash, sweetgum, and yellow-poplar. One of three cultural treatments--no cultivation, mowing, or clean cultivation (cross-disking plus hoeing)--was randomly assigned to a plot. Growth and survival of yellow-poplar was excellent during the first growing season, but all the seedlings were killed during the second season when the site was flooded to a depth of 1.8 m from late March to late May. None of the other species was harmed by the flood. Nuttall, cherrybark, and water oak had poor survival and growth, which was probably due to the high soil pH (8.0). Survival and height and diameter growth were significantly higher in the clean cultivated plots. After 4 years, height and diameter growth were highest for cottonwood, followed by sycamore, green ash, sweetgum, and pecan. Average survival was 8% (excluding the oaks and yellow-poplar) for the clean cultivated plots, 65% for mowed plots, and 61% for uncultivated plots.

Kennedy, H.E., Jr., and R.M. Krinard. 1974. 1973 Mississippi River flood's impact on natural hardwood forests and plantations. U.S. Forest Service Research Note SO-177. 6 pp.

The impacts of the 1973 Mississippi River spring flood (6-11 ft maximum depth) on bottomland hardwood species are described. Most of the damage was to planted and natural bottomland hardwood stands less than 1 year old. Species suffering heavy mortality included cottonwood, sweetgum, yellow-poplar, and Shumard oak; sycamore and green ash plantings showed good survival. All yellow-poplar of all ages were killed. Trees of other species that were older than 1 year suffered some damage but were generally able to survive the flood. There were some indications that seedlings survived better than planted cuttings. The length of time of inundation seemed to be a factor in overall tree survival. Nuttall oak acorns that were direct-seeded the year before survived the flood. Siltation of up to 5 ft occurred, but did not adversely affect well established trees. Oxygen levels in the flood waters were generally adequate and did not appear to be a prime cause of mortality.

Kennedy, H.E., Jr., and R.M. Krinard. 1985. Shumard oaks successfully planted on high pH soils. U.S. Forest Service Research Note SO-321, New Orleans, LA. 3 pp.

This paper reveals that many Mississippi riverfront soils are devoid of oak forests, and planting trials with Nuttall, cherrybark, and water oaks have not been successful on such soils. One reason may be the high pH of many riverfront sites, which may range from 7.5 to 8.0. Three trials with Shumard oak, however, have proved successful. Shumard oak was planted in 1959 at Archer Island in Washington County, MS, on Robinsonville sandy loam, and at Huntington Point in Bolivar County, MS, in 1974 and 1975 on Commerce silt loams. Nursery-grown, 1-O bareroot seedlings were planted at 10 by 10 ft spacings on sites that were cleared of a natural stand of mixed hardwoods and prepared by shearing, root raking, and disking. Plantings were clean cultivated during the first growing season, but no intensive weed control was applied afterwards. After both 12 and 25 growing seasons, survival averaged 86% at Archer Island. Survival at Huntington Point was 73% after 10 growing seasons at one site and 80% after 11 growing seasons at the other site. Diameter growth averaged 0.5 inch/year for all three plantings, while height growth averaged 3.0 to 4.0 ft/year. In another study, Nuttall, water, and cherrybark oaks were planted within 200 ft of one of the Shumard oak plantings at Huntington Point. The leaves of the former three species turned yellow early in each growing season, and the trees grew very little. After four growing seasons, survival was only 10%-40%.

Kennedy, H.E., Jr., B.E. Schlaegel, and R.M. Krinard. 1986. Nutrient distribution and tree development through age 8 of four oaks planted at five spacings in a minor stream bottom. Pages 65-70 in Proceedings of the 1986 southern forest biomass workshop, Knoxville, TN.

This paper reports on the results of experiments with eight hardwood species planted at five spacings in a minor stream bottom in southeastern Arkansas, about 10 mi south of Monticello. The species planted were water, Nuttall, cherrybark, and swamp chestnut oaks, sycamore, sweetgum, cottonwood, and green ash; however, only data from the oaks were presented in the paper. The soil series was Arkabutla, a somewhat poorly drained silty alluvium. Spacings used were 2 by

8, 3 by 8, 4 by 8, and 12 by 12 ft; the minimum of 8 ft between rows was chosen to allow cultivation during the first growing season. Data are presented on total dry weight of trees (without leaves) per acre, cubic feet of wood per acre, leaf weights per acre, survival, dbh, and height after eight growing seasons. Spacing significantly affected all variables, except survival and height, and all variables except survival were different for the various species. Survival for all oak species ranged from 75% for 8 by 8 ft spacing, to 83% for 4 by 8 and 12 by 12 ft spacing. Water oak had the largest average dbh (2.2 inches) and the largest average height (20.1 ft), followed by Nuttall oak (2.1 inches and 16.7 ft), cherrybark oak (1.8 inches and 15.8 ft), and swamp chestnut oak (1.3 inches and 11.0 ft). Yields (by weight and volume) were larger with small spacings, though yields per tree were lower.

Klawitter, R.A. 1963. Sweetgum, swamp tupelo, and water tupelo sites in a South Carolina bottomland forest. Ph.D. Dissertation. Duke University, Durham, NC.

Sweetgum, swamp tupelo, and water tupelo habitats were studied in a coastal plain bottomland forest adjacent to the Santee River in South Carolina. Site variables evaluated included elevation, hydrology, woody understory vegetation, and soil characteristics. Results showed that sweetgum sites were better drained, with a higher pH, than tupelo sites. Water tupelo soils exhibited greater clay content and depth of flooding; swamp tupelo soils showed lowest pH. Abundant soil moisture and long hydroperiods were positively related to growth of water tupelo. Laurel oak in the understory was associated with well-drained sites at the lower margins of first bottoms. Green ash preferred swampy sites that remained wet for long periods without deep flooding. American elm occurred mostly along the upper slopes of the swamp and lower edges of the first bottom. Carolina ash, red maple, and green ash decreased in abundance with the increased height of water tupelo.

Krinard, R.M., and R.L. Johnson. 1976. El-year growth and development of bald cypress planted on a flood-prone site. U.S. Forest Service Research Note SO-217, New Orleans, LA. 4 pp.

Results are given of a study in which a total of 896 one-year-old cypress seedlings were planted on a Sharkey clay site in the Delta Experimental Forest in Washington County, MS, in February 1955. The site was about 20% ridge, 20% slough, and 60% flat-slough, with a 3-ft difference in elevation between the flat and the slough. About 1-2 ft of water covered the slough in winter. The site flooded frequently, and three earlier attempts to plant cottonwoods in the area failed due to excessive flooding and heavy competition from vines. Survival after 21 years was 41%, but some of the cypress were suppressed and were not expected to survive much longer. Invading species noted were green ash, boxelder, sugarberry, persimmon, blackwillow, and cottonwood, which collectively accounted for about 26% of the total density. Density of cypress was about 74%.

Krinard, R.M., and R.L. Johnson. 1981. Flooding, beavers and hardwood seedling survival. U.S. Forest Service Research Note SO-270, New Orleans, LA. 6 pp.

Trial plantings made for three successive years on cleared, clay-capped batture land at Ajax Bar in Issaquena County, MS, are discussed. Seven species were planted, including cottonwood, sycamore, green ash, sugarberry, swamp chestnut oak, Shumard oak, and pecan. In the first year there was no flooding, but during the second year flooding occurred for varying periods from late winter through early summer. No beaver damage was noted when there was no flooding, but during the flooded periods, significant damage to all species (with the possible exception of sycamore) was observed. The beavers apparently damaged the seedlings while they were in shallow water, pulling the seedlings out of the ground and eating the root system up to about the root collar. Consecutive long rows of damaged trees were observed. Up to 43% of the seedlings of some species were destroyed. Shumard oak was hurt most by the floods, and green ash and sycamore fared best. Green ash and sycamore are recommended for planting if substantial first-year flooding is likely.

Krinard, R.M., and H.E. Kennedy, Jr. 1981. Growth and yields of 5-year-old planted hardwoods on Sharkey clay soil. U.S. Forest Service Research Note SO-271, New Orleans, LA. 3 pp.

Cottonwood, sycamore, green ash, sweetgum, and Nuttall oak seedlings were planted on a Sharkey clay site. The seedlings were planted on a 10 by 10 ft spacing, and the plots were cross-disked or mowed three to five times a year for six growing seasons. Before the sixth season, height and diameter of all trees were measured, and a total of 12 trees of each species were felled and weighed. Mowed plots of sweetgum and Nuttall oak were not considered because survival was less than or equal to 50%. Survival on the other plots ranged from 81% for mowed cottonwood to 99% for disked sycamore. Whether mowed or disked, sycamore and green ash had 95% or better survival. Mean dbh and height ranged from 4.0 inches and 25.8 ft for disked cottonwood to 1.0 inch and 8.6 ft for disked Nuttall oak. Disked plots consistently had higher survival and better diameter and height growth than mowed plots.

Krinard, R.M., and H.E. Kennedy, Jr. 1983. Ten-year growth of five planted hardwood species with mechanical weed control on Sharkey clay soil. U.S. Forest Service Research Note SO-303, New Orleans, LA. 4 pp.

Studies on mechanical weed control are reported for five species of southern hardwoods (cottonwood, sycamore, green ash, sweetgum, and Nuttall oak) that were planted on a Sharkey clay site on the Delta Experimental Forest, near Stoneville, MS. Plots, consisting of 24 trees of one species planted on a 10 by 10 ft spacing, were mowed or disked from three to five times annually for the first 5 years. After the fifth year, plots with 80% or more survival for trees more than 4.5 ft tall were thinned to six trees each, or an equivalent of 20 by 20 ft spacing. Mowing or disking treatments, one to three times annually, for years 6-10 were randomly assigned. Some plots were mowed or disked each year for 10 years; some plots were mowed the first 5 years and disked years 6-10, and some were disked the first 5 years and mowed years 6-10. Disking resulted in better growth of all species over the first 5 years, but for years 6-10, there was only a slight difference in height, dbh, or volume between treatments. Overall height growth through 10 years was from 1.7 to 4.9 ft/year, depending on species-treatment combination. Cottonwood was the tallest species overall after 10 years, followed by sycamore, green ash, sweetgum, and Nuttall oak. Soil moisture was not significantly different between treatments, and after 10 years there was no significant difference in soil properties (pH, organic matter, N, P, K, Ca, and Mg) between treatments.

Krinard, R.M., and H.E. Kennedy, Jr. 1987. Fifteen-year growth of six planted hardwood species on Sharkey clay soil. U.S. Forest Service Research Note SO-336, New Orleans, LA. 4 pp.

This article discusses further results (see Krinard and Kennedy 1983) of mowing and disking experiments on six hardwood species (cottonwood, sycamore, green ash, sweetgum, Nuttall oak, and pecan) which were planted on a Sharkey clay site on the Delta Experimental Forest, near Stoneville, MS. Mowing or disking treatments for years 6 through 10 were found to have little effect on growth; therefore, results are discussed relative to the first 5 years of weed control treatments. At age 15, trees on plots disked the first 5 years were significantly taller and larger in dbh than trees on mowed plots, but overall the differences were only 1.3 ft in height and 0.6 inches in dbh. The relatively small differences after age 15 imply different growth patterns for trees in disked versus mowed plots. One possible explanation is that mowing, which results in higher competition initially, may cause tree roots to grow deeper where extra nutrients and water may speed growth in later years. Average dbh and height after 15 years on the disked plots were: cottonwood, 11.0 inches and 60.4 ft; sycamore, 6.5 inches and 37.7 ft; green ash, 6.5 inches and 36.3 ft; sweetgum, 5.9 inches and 30.6 ft; Nuttall oak, 5.8 inches and 20.2 ft; and pecan, 3.4 inches and 21.7 ft.

Larsen, H.S. 1963. Effects of soaking in water on acorn germination of four southern oaks. Forest Science 9(2):236-241.

Southern red oak, willow oak, laurel oak, and overcup oak were tested to determine whether flooding is instrumental in controlling the distribution of some southern oaks by differential effects on acorn germination. Two soaking variables were tested: length of soaking and water temperature. Soaking periods were 1, 2, 4, and 8 weeks. Two temperature levels were imposed--the first a controlled range of 44.0-46.6 °F, and the second an unregulated diurnally fluctuating range of 55-64 °F. Lots of 50 acorns each were subjected to each time/temperature treatment, with unsoaked lots of each species serving as controls. After soaking, all seed lots were sown simultaneously in moist sand at a depth of 1/2 to 3/4 inches, and kept at a soil temperature of 73-81 °F. The results did not support the hypothesis that injury to acorns by flooding is a primary reason for exclusion of dry-site species from bottomland sites. Average germination for all soaking treatments for southern red oak (the driest-site species tested) was 87%, compared to 92% for unsoaked acorns. The minimum germination observed was 66% for laurel oak soaked for 2 weeks, compared to 77% for the control. Overcup oak had the lowest overall germination (82%), but showed improvement in a second test when the acorn shells were opened prior to soaking.

Leitman, H.M., J.E. Sohm, and M.A. Franklin. 1983. Wetland hydrology and tree distribution of the Apalachicola River flood plain, Florida. U.S. Geological Survey Water Supply Paper 2196, Alexandria, VA. 52 pp.

This assessment focuses on hydrology and productivity of the floodplain forest associated with the Apalachicola River in northwest Florida. Forest types were found to be highly correlated with depth of water, duration of inundation and saturation, and water-level fluctuation, but not water velocity. Most types dominated by tupelo and baldcypress grew on permanently saturated soils inundated 50%-90% of the time (an average of 75-225 consecutive days during the growing seasons from 1958-80). Most forest types dominated by other species grew in areas saturated or flooded 5%-25% of the time (an average of 5-40 consecutive days during the growing seasons from 1958-80). Average basal area and density for all forest areas sampled were 46.2 m^2/ha and 1,540 trees/ha, respectively. The relative tolerance of bottomland tree species to inundation is discussed.

Limstrom, G.A. 1960. Forestation of strip-mined land in the central states. U.S. Forest Service Central States Forest Experiment Station Agricultural Handbook No. 166, Washington, DC. 74 pp.

The publication is an excellent technical guidebook based on research studies beginning in 1937. The author notes that commonly accepted reforestation practices are not always successful because strip-mine spoil banks are so different from most natural planting sites physically, chemically, and biologically. Emphasis is placed on the where, when, and how of tree planting on mined lands as related to existing mining and reclamation methods. The report includes recommendations and discussions of the effects of various site conditions and planting methods. Several typical bottomland forest species are included in the data and discussion, including green ash, eastern cottonwood, silver maple, and sycamore. Also discussed are the detrimental effects of grading on soil moisture and aeration, and the ecology of natural forestation.

Limstrom, G.A. 1963. Forest planting practice in the central States. U.S. Forest Service Central States Forest Experiment Station Agricultural Handbook 247, Washington, DC. 69 pp.

This handbook provides useful guidance on a number of topics including species selection for various sites, site preparation, where to obtain trees, quality and care of planting stock, planting methods and patterns, care and management of plantations, forest pests and diseases, how to make planting plans, and treatment of seeds. The States included are Illinois, Indiana, Iowa, Kentucky, Missouri, and Ohio.

Lotti, T. 1959. Selecting sound acorns for planting bottomland hardwood sites. Journal of Forestry 57:923.

The article discusses methods of determining the viablity of acorns to be used for planting hardwoods. Nut or acorn weevils seriously limit the viability of acorns. Flotation in water is a commonly accepted method of separating weeviled from sound acorns before planting; sound acorns usually sink. The soundness of Shumard oak and cherrybark oak acorns, however, can be judged with certainty by the color of the basal or cup scar. If the circular scar is a light tan, the acorn is sound; if a dull brown, the acorn is defective. These color relationships are easily established in actual practice. Since Shumard and cherrybark are red oaks, this method may have a broader application to the red oak group. The method does not work well, however, with swamp chestnut oak, which belongs to the white oak group. The success of the visual selection, as evidenced by high germination percentages, makes further weevil treatment unnecessary.

Loucks, W.L., and R.A. Keen. 1973. Submersion tolerance of selected seedling trees. Journal of Forestry 71:496-497.

This Kansas study helps to identify seedlings which have high submersion tolerance. Seedlings of 10 species were covered with 2 ft of water for periods of 1, 2, 3, and 4 weeks to test submersion tolerance. The seedlings were planted in five flat-bottom ponds constructed near Manhattan, KS, in an area of Wymore silty clay loam soil. Four of the ponds were filled with well water and one was left unflooded as a control. Species planted were green ash, baldcypress, silver maple, pecan, cottonwood, honeylocust, bur oak, boxelder, Siberian elm, and black walnut. There was no significant mortality in any species in the 1- and 2-week submersion treatments. In the 3-week treatment, survival was still 100% for green ash, baldcypress, cottonwood, and silver maple, but dropped to between 44% and 67% for the remaining species. Survival after 4 weeks ranged from zero for black walnut to 100% for green ash and baldcypress. The remaining species in order of survival from highest to lowest were silver maple, pecan, cottonwood, honeylocust, bur oak, boxelder, and Siberian elm.

Maisenhelder, L.C., and C.A. Heavrin. 1957. Silvics and silviculture of the pioneer hardwoods--cottonwood and willow. Pages 73-75 in Proceedings of the 1956 annual meeting of the Society of American Foresters.

The authors cover five topics related to the silvics and silviculture of cottonwood and willow in the lower Mississippi Valley: (1) site development, (2) seedling establishment, (3) establishment and growth, (4) natural enemies, and (5) artificial regeneration. The site development section describes the formation of new land on "point bars" in the river, where cottonwood and willow typically are found. The next two sections describe the natural establishment and growth of cottonwood and willow on these new lands. Natural enemies discussed in the fourth section include fire (both cottonwood and willow are very susceptible); sustained submergence of young trees during the growing season; cattle, hog, and deer browsing; and defoliating insects, especially on cottonwood. The final section briefly describes propagation and plantation establishment from cuttings, which is especially suitable for clearcut areas and old agricultural fields. It is recommended that cuttings be taken from 1- to 3-year-old seedlings or sprouts; individual cuttings should be about 20 inches long and from 3/8 to 3/4 inches diameter at the small end. The cuttings should be placed 15 inches into the ground; planting into a slit made by a sub-soil plow is preferable to using a planting bar if tree roots are not a problem. Spacing of about 10 by 10 ft is desirable to allow for weed control. Weeds should not be allowed to exceed three-fourths of the height of the seedlings during the first growing season. On good sites under favorable conditions, first year survivals of 75%-90% may be expected, with an average height growth of about 5 ft. Growth of 10 ft in height and 1 inch in dbh have been attained.

Maki, T.E., A.J.Weber, D.W. Hazel, S.C. Hunter, B.T. Hyberg, D.M. Flinchum, J.P. Lollis, J.B. Rognstad, and J.D. Gregory. 1980. Effects of stream channelization on bottomland and swamp forest ecosystems. University of North Carolina, Water Resources Research Institute, Raleigh.

This study evaluates the effects of stream channelization on the bottomland-swamp forest ecosystems of eastern North Carolina. Groundwater regimes in the floodplains were monitored to provide a basis to compare plant communities. Aboveground biomass of shrub and herbaceous vegetation was found to be inversely related to the number of inundation periods per year. Competition from this "lesser vegetation" was deleterious to planted and naturally regenerated tree seedlings along the channelized streams. Regeneration of water tupelo, swamp blackgum, and baldcypress appeared to have been reduced in channelized areas; these species were particularly sensitive to competition from overstory vegetation and the profusion of vines, grasses, and briars associated with the decrease of groundwater levels in channelized swamps. Survival and growth of planted tupelo seedlings were greater along non-channelized streams than along channelized streams; the latter seedlings were adversely affected by fierce competition from honeysuckle and blackberry canes. Regeneration in cutover areas was sometimes less than in non-cut areas because the cutover areas exhibited an increase in vines, briars, and other woody reproduction which precluded the reestablishment of trees. This situation could persist for an indefinite period of time unless flooding or some other factors reduce competition. For comparison, the authors reported on a well-managed swamp forest stand along the Roanoke River at Tillery, Halifax County, NC, that originated from a clearcut of a tupelo tract about 70 years earlier. With little or no overstory competition, water tupelo and some baldcypress became established and grew well. After about 70 years, the Tillery stand contained a standing volume of about 1,000 m^3/ha in non-cut areas and from 350 to 625 m^3/ha in areas thinned in 1962.

Malac, B.F., and R.D. Heeren. 1979. Hardwood plantation management. Southern Journal of Applied Forestry 3(1):3-6.

In this paper, some of the hardwood silvicultural practices of Union Camp Corporation are detailed. These practices are based on 10 years of hardwood plantation research carried out near Franklin, VA, and include seed collection, site selection, planting stock, site clearing, site preparation, planting, spacing, competition control, fertilization, harvesting, and coppicing. Species planted include sycamore, green ash, sweetgum, and willow, water, and laurel oaks. All seed is collected from the best available local trees, but the company is in the process of developing clonal seed orchards. Sites chosen for planting hardwoods have a sandy loam or loam surface fairly high in organic matter, are moderately well-drained, and have a water table to within 4 inches of the surface during portions of the year. Only large, healthy seedlings, with a minimum root collar diameter of 3/8 inch and a top height of at least 2 ft are planted. All sites are intensively cleared, except for recently abandoned agricultural land. Some sites are disked prior to planting, abandoned fields with plow pans or shallow topsoil are subsoiled, and wet sites are bedded. Seedlings are planted with tractor-drawn machine planters modified to handle large seedlings. Sycamore and the oaks are planted on a 10 by 10 ft spacing and green ash and sweetgum on a 8 by 12 ft spacing. Depending on site and weed growth, plantations are disked on the average of two to three times a year for at least the first 2 years. As a rule, fertilizer is applied during the first cultivation; applications vary, but often about 250 lb/acre of triple superphosphate or diammonium phosphate are used. Harvesting is planned for between ages 12 and 15, with coppice regeneration for at least two rotations.

McDermott, R.E. 1954. Effects of saturated soil on seedling growth of some bottomland hardwood species. Ecology 35(1):36-41.

This study focuses on seedling survival in saturated soils. Young seedlings (less than l-month-old) of American elm, winged elm, red maple, sycamore, hazel alder, and river birch were subjected to saturated soil conditions for periods of 0, 1, 2, 4, 8, 16, and 32 days. Each treatment was applied to 20 seedlings in four pots of five seedlings per pot. After flooding, the seedlings were kept at or above field capacity under conditions of about 50% sunlight and at high soil temperatures. Heights of the seedlings were measured at the end of 32, 42, and 52 days. Compared to the no-flooding controls, all species showed patterns of stunting in height growth. River birch showed evidence of stunting for all saturation periods greater than 1 day, and red maple was stunted by all but the 4-day saturation period. Both species recovered rapidly in well-drained soil conditions. Sycamore was significantly stunted only by the 32-day treatment, but recovered fairly rapidly. American elm was not affected by 1 or 2 days of saturation, had minor stunting after 4 days of saturation, and was permanently stunted by 8-, 16-, and 32-day saturation periods. Winged elm showed a beneficial effect of a l-day saturation; 2, 4, and 8 days had no apparent effect, and 16 and 32 days of saturation had a negative effect on growth. Hazel alder height growth was promoted by all saturation periods except 32 days, for which no significant effect was found. Survival for hazel alder after 32 days saturation was only 40%, which is unusually low, compared to 100% survival for red maple, the elms, and river birch, and 95% for sycamore.

McElwee, R.L. 1965. Direct seeding hardwoods in river bottoms and coastal plains. Pages 110-115 in Proceedings of the direct seeding workshops, Alexandria, LA, and Tallahassee, FL.

In this symposium presentation, the author addresses three questions: (1) Why direct seed? (2) What are some important considerations for direct seeding? and (3) Can we regenerate bottomland hardwood areas by direct seeding based on current knowledge of the subject? Direct seeding is advantageous in some bottomland situations because it costs about 25%-33% as much and requires less labor than hand-planting, which is often required in bottomland areas because of saturated soils. The effects of root disturbance from lifting and outplanting hardwood seedlings are also eliminated. Important considerations for direct seeding include species, site, and equipment available. Most important bottomland species perform better an sites that have been disked or bladed so that mineral soil is exposed. Most species do better in full sunlight, and require protection from seed predators. Enough is known about direct seeding for successful application in some cases, but more needs to be learned about species-site relationships; what site preparation is needed; collection and storage of seed; sowing rates; and protection from rodents.

McKnight, J.S., and R.L. Johnson. 1966. The techniques of growing hardwoods. Forest Farmer 25(7):59-68.

Management of southern hardwoods, including initial planning, protection, improvement of abused stands, thinning, harvesting systems, and artificial regeneration, is discussed. Informative tables are presented on utility classes; lo-year average diameter growth rates for 13 species and species groups in unmanaged stands; expected regeneration following harvest cutting systems in different species associations; soil suitability by species and physiographic zones; and planting information. The latter table contains information for 9 species or species groups on recommended length for root pruning, top length, and root collar diameter; adaptability to machine planting; response to fertilizer; usual first year growth: suitability for wet sites; and susceptibility to browsing and insect damage, The section on artificial regeneration lists five major rules that have been developed: (1) match species to sites (the soil suitability and physiographic zones are referred to as guidance); (2) prepare the planting site properly (which means removal of competing vegetation and, in abandoned fields, subsoiling); (3) use good planting stock; (4) plant properly: hardwood seedlings are easily damaged by exposure of roots to drying or planting at improper depths; and (5) care for the new plantation properly: control of weeds increases the early growth of all species, especially cottonwood. More needs to be learned about plantation establishment on degraded agricultural fields, optimal spacing, and direct seeding.

Moore, W.H. 1950. Survival and growth of oaks planted for wildlife in the flatwoods. U.S. Forest Service Research Note SE-286, Asheville, NC. 4 pp.

This research note reports on an experiment to assess the potential for creation of hammocks. Two-year-old live oak and laurel oak seedlings were planted in a cut-over pine flatwoods area in Charlotte County, FL. The predominant soil series in the area are the Immokalee (pine-palmetto), which are imperfectly drained acid sands with an organic-stained pan, and Charlotte (wet prairie), which are poorly drained shallow sands over calcareous materials; both soils are saturated much of the year. Treatment plots were established to compare the two oak species; sites (pine-palmetto versus wet prairie); livestock grazing (grazed versus ungrazed); and site preparation (bedding versus tilling). Beds were 4-5 m across, 45-60 cm high, well-drained, and devoid of vegetation. After 8 years, survival of live oak was 95% and laurel oak, 76%. No significant differences were found between sites, site preparation, and grazing treatment. The better survival of live oak may have been due to the unusually dry year following outplanting; live oak appeared better able to survive on the drier planting sites. Height growth was influenced by species, site preparation (the most important factor), and grazing treatment. Trees on tilled plots grew little (averaging only 0.1 m/yr). On beds, live oak averaged 2.1 m after 8 years and laurel oak, 1.3 m. Both species grew better on ungrazed plots; no significant difference was found between the pine-palmetto and wet prairie sites. Results indicated that bedding would be required to establish oaks in the low flatwoods of south Florida.

Nawrot, J.R., and S.C. Yaich. 1983. Slurry pond forestation: potential and problems. Pages 180-194 in Proceedings of the third annual conference on better reclamation with trees. Purdue University, Terre Haute, IN.

The paper discusses factors important to reforestation efforts on inactive slurry impoundments in Illinois and Indiana. Techniques for correcting problems associated with acid-base balance, surface stability, and moisture zones are covered. Earlier studies had revealed that hydrophytic species such as baldcypress and river birch survived well in moist soil zones near impoundment decant areas, and exhibited growth rates comparable to those of individuals growing in natural soils. Other species expected to exhibit good survival and growth include green ash, pin oak, swamp white oak, persimmon, silver maple, black locust, and sycamore. The authors note the value of black locust as a nurse crop for marginal sites; a litter layer and organic enriched zone extending 1.5-2 inches into the slurry surface occurred on a 25-year-old inactive site. Because of the highly unpredictable site conditions that may exist within various slurry impoundments because of coal-seam geology, mining and preparation practices, disposal management, and the period and extent of weathering and leaching, numerous factors should be evaluated prior to planting to avoid poor planting success or complete failure. These factors include hydrogeochemical conditions, nutrient and neutralization amendment requirements and application, organic matter enhancement, moisture extreme regulation, and temperature moderation.

Nelson, T.C. 1957. Rooting and air-layering some southern hardwoods. In Proceedings of the fourth southern conference on forest tree improvement; January 8-9, 1957; Athens, GA.

This paper summarizes studies that have been underway at the Athens-Macon Research Center of the Southeastern Forest Experiment Station. The studies had two main objectives: (1) to increase the number of species that can be successfully planted from cuttings in the Georgia Piedmont; and (2) to develop methods of vegetative propagation necessary for work in hardwood genetics and tree improvement. Propagation in nursery beds through rooting of hardwood cuttings has been successful for cottonwood, sycamore, and yellow-poplar, though only the first two species were then successfully out-planted. A half-acre out-planting of cottonwood cuttings on a bottomland site near Athens, GA, had a 1-year survival of 88% and an average height of 7 ft. The best trials with sycamore had 65% survival and a maximum height growth of 8 ft after one growing season. Best survival and growth of sycamore were obtained from butt-cuttings. Softwood cuttings of yellow-poplar, sweetgum, and water oak planted in nursery beds have been unsuccessful. Tests are now underway with sycamore cuttings to test the effect of various site-preparation techniques on initial survival and growth of cuttings. Cottonwood has been the only species to show a relatively high percentage of success with first attempts at air-layering. Some success was obtained with sycamore, green ash, and sweetgum, but not with yellow-poplar, southern red oak, cherrybark oak, red maple, and flowering dogwood.

Philo, G.R. 1982. Planting stock options for forestation of surface-mined lands. Pages 65-74 in Post-mining productivity with trees. Proceedings of a 1982 seminar in the Department of Botany; Southern Illinois University at Carbondale.

In this paper, factors affecting the choice of planting stock in relation to forestation of surface-mined lands are discussed. Good spring establishment of trees in southern Illinois can be obtained with bare-root seedlings for most of the species commonly available at State and private nurseries. Direct seeding of large-seeded species is also recommended since this practice can extend the planting season into fall, allows for selection of seed source, and cultivates good root form that should enhance the short- and long-term growth of trees. Exceptional establishment rates were noted for the following oaks: black, bur, pin, red, shingle, and particularly Shumard and chestnut. Black walnut from direct seeding also performed well, especially in regard to the root form of established seedlings. Seeded hickory exhibited only moderate success although results were variable. Smaller-seeded species, such as black cherry, persimmon, and hackberry, have exhibited poor establishment rates. For those species not readily established with bare-root seedlings or seed, container seedlings may be appropriate. Inherent in any container system is a degree of distortion of the seedling roots, which could restrict tree growth. The degree of success usually achieved with bare-root stocks or direct seeding and the relatively low cost of these methods have typically led to their use in surface-mined reclamation. On the other hand, container stock may be appropriate when inoculating seedlings with mycorrhizal fungi or other organisms to enhance survival and growth. For bare-root stock, the author recommends pruning taproots to 20 cm, lateral roots to 5 cm, and shoots of hardwoods to 20 cm to facilitate handling and planting.

Putnam, J.A., G.M. Furnival, and J.S. McKnight. 1961. Management and inventory of southern hardwoods. U.S. Forest Service Agriculture Handbook No. 181. 101 pp.

This handbook provides guidance for management and inventory of both bottomland and upland hardwoods throughout the Southern United States. General topics include (1) the forest, (2) preliminary management, (3) advanced management, and (4) inventory. A selected bibliography with 175 references is also included. The first section contains a good discussion of species-site relationships, and subsections on species, stand origins, damaging influences, and utilization. Most of the rest of the handbook is geared toward the management of existing hardwood forests. Planting and direct seeding are not covered. Management topics include reconnaissance, boundary location, protection, compartmentation, timber stand improvement, the first cut, and stocking and growth considerations. A useful table on southern hardwood species and chief softwood associates is provided in the first section. It gives scientific and several common names for each species and information on occurrence in bottomlands and in uplands, growth rate, shade tolerance, reproduction, susceptibility to damage, value and primary uses, and general remarks.

Rafaill, B.L., and W.G. Vogel. 1978. A guide for vegetating surface-mined lands for wildlife in eastern Kentucky and West Virginia. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-78/84, Washington, DC. 89 pp.

This document contains useful information on species of trees and vegetation suitable for revegetation of surface-mined areas, including availability of plants and planting and seeding methods.

Raisanen, D.L. 1982. Survival of selected tree species on sites reclaimed to various reclamation standards. Pages 93-102 in Post-mining productivity with trees. Proceedings of a 1982 seminar in the Department of Botany; Southern Illinois University at Carbondale.

This paper gives results of a study of 26 plots planted in the spring of 1981 at five surface-mined and reclaimed sites in southern Illinois to evaluate tree survival relative to species and treatments. Tree species included black walnut, black cherry, baldcypress, green ash, hackberry, pin oak, red oak, silver maple, sweetgum, and sycamore. Treatments consisted of application of a fertilizer tablet and a herbicide, planting of seedlings into four different herbaceous cover mixtures, and ripping to a depth of 24 inches: Species were mechanically planted as bare-root seedlings in March 1981; a survival count was made in the fall. Survival rates for the above species ranged from 35% for black cherry to 91% for silver maple. Baldcypress had a survival rate of 45% and hackberry, 46%, and all others were ≥ 59%. Herbicide use increased species survival by 80%. Amizine herbicide (a mixture of Amitrol-T, a post-emergent, and Simizine, a pre-emergent) was applied at 4 lb of active ingredient per acre. The results of fertilization and ripping were inconclusive. Survival rates of the trees grown on three of the four herbaceous cover mixtures were about the same (58%, 59%, and 61%); the survival rate on one mixture was somewhat less, at 51%. The results of this study identified species selection, use of herbicides, and quality planting procedures as important factors in successful plantings.

Richards, T.W. [no date]. Establishing trees by direct-seeding. Reclamation news and views. Cooperative Extension Service. University of Kentucky, Lexington, KY. 6 pp.

Direct-seeding as an alternative and supplement to planting seedlings is discussed in this paper. Advantages of direct seeding include lower labor costs, less planting time per acre, greater species availability, longer planting season, and less chance of root deformity. The author notes that reports of direct-seeding failures are common in the literature and that some references discourage this method; however, he points out that most failures are a result of improper handling and poor planning. Species that have direct-seeded well on surface-mined lands are discussed. The best are the larger-seeded species, including many oaks, black walnut, and Chinese chestnut, but other species may have application in direct-seeding use. Seeding trials have been limited by seed availability and many species have not been sufficiently tested.

Richards, T.W., R.F. Wittwer, and D.H. Graves. 1982. Direct-seeding oaks for surface-mine reclamation. Pages 57-62 in Post-mining productivity with trees. Proceedings of a 1982 seminar in the Department of Botany; Southern Illinois University at Carbondale.

Results are given by the University of Kentucky Department of Forestry for direct-seeding studies on surface-mined land. A consistent pattern of successful establishment and growth has been shown for a variety of oak species, including northern red oak, pin oak, chestnut oak, bur oak, and sawtooth oak. Proper choice of species for specific site conditions is important. Germination and survival can be improved by amendments to the site, such as mulch or mulch and fertilizer. Herbaceous competition is also an important factor affecting long-term survival and growth. Use of a mechanical planter for row-seeding in mine soils can shorten planting time and reduce labor costs; use of spray nozzles on the planter for herbicide application can increase the efficiency of the planting operation.

Robertson, D.J. [1985]. Sink Branch: stream relocation and reclamation by the Florida phosphate industry. Florida Institute of Phosphate Research, Bartow, FL. Draft Final Report (Unpublished). 61 pp.

This report describes follow-up monitoring and reevaluation of an experimental project at Sink Branch (Polk County, FL). Mobil Chemical Company established the project in December 1979 when 0.3 km of Sink Branch, a tributary of the Peace River, was diverted into an artificial channel excavated on phosphate-mined land. Although the study addressed hydrologic and aquatic factors, its primary purpose was to test methods to reestablish a riparian forest along the new channel. The study, conducted on a l-ha area of reclaimed land, included four treatments: application of two different-sized layers of organic soil (0.5 and 1 ft), fertilization, and a no-treatment control. Tree spaded, potted, and bare-root seedlings were planted. Species planted included sweetgum, live oak, Florida elm, slash pine, sweetbay, red maple, baldcypress, green ash, and dogwood. Irrigation water was applied. Three years after planting, the overall survival rate was 29%; the site contained 213 trees per acre, including nine hardwood and one coniferous species. This was sufficient to satisfy the wooded wetland reclamation requirements of Florida, which call for a minimum of 200 indigenous hardwood and coniferous trees per acre. Survival varied among species, planting stocks, and treatments; the responses warrant additional study before conclusions can be reached. Except for slash pine, none of the species exhibited significant differences in growth using the various treatments. The pines responded best in mulched plots, and grew less rapidly in the fertilized and control plots.

Ruesch, K.J. 1983. A survey of wetland reclamation projects in the Florida phosphate industry. Dames and Moore, Lakeland, FL, and Florida Institute of Phosphate Research, Bartow. 59 pp. t appendixes.

This survey identifies (maps provided) and summarizes 35 wetland reclamation projects in the Florida phosphate industry as of Spring 1983. Information was obtained through 51 questionnaires mailed to individuals or organizations, and included size, location, project goals, revegetation methods, plant survival, monitoring, and techniques that failed or were highly successful. Most of the projects were also field inspected. Of the total, 20 projects were completed, 10 were in various stages of construction, and plans had been completed for 5 others. Most of the wetland projects lacked quantitative monitoring and the success of many techniques was not well documented. One apparently successful technique which was frequently used was spreading a layer of organic soil obtained from another wetland to encourage the reestablishment of wetland vegetation.

Rushton, B. 1983. Examples of natural wetland succession as a reclamation alternative. Pages 148-189 in D.J. Robertson, ed. Reclamation and the phosphate industry. Proceedings of a symposium; 26-28 January, 1983; Clearwater Beach, FL. Florida Institute of Phosphate Research, Bartow.

Natural succession occurring on four clay-settling ponds after 2 to 60 years and one 40-year-old control area is discussed. Field measurements were taken at each site on trees and shrubs (including seedlings), herbaceous vegetation, accumulated litter biomass, leaf area index, optical density, and water depth. Succession was found to be taking place, but some sites were in an arrested willow stage, possibly because seeds for the next successional stage were unable to reach the site or become established. Only one site (30 years old) had typical bottomland hardwood vegetation developing, and this only occurred on parts of the site that were periodically inundated. It was concluded that improved seeding and control of hydroperiod may provide means for establishing wetland forests on reclaimed clay-settling pond sites.

Schrand, W.D., and H.A. Holt. 1983. Herbicides and plantation establishment on reclaimed mined lands. Pages 146-157 in Proceedings of the third annual conference on better reclamation with trees. Purdue University, Terre Haute, IN.

This paper discusses the use of selected herbicides for weed control in forest and mine-land revegetation, and provides a bibliography. Herbicides covered include Princeps 80W (simazine); Amitrole-T (amitrole); Dowpon M (dalapon); Roundup (glyphosate); Kerb 50W (pronamide); 2, 4-D; Sulflan; Oust; and Poast. Herbaceous and woody plants exhibit various levels of tolerance to different herbicides. In addition, application rates and environmental conditions can determine the degree of success from site to site. Performance of the herbicides for site-specific test conditions are described. The cost of herbicides and the legal implications of use inconsistent with label instructions are important considerations.

Seifert, J.R., P.E. Pope, and B.C. Fischer. 1985. The effects of three levels of site preparation on planted swamp chestnut oak on a poorly drained site. U.S. Forest Service General Technical Report SO-54, New Orleans, LA.

Swamp chestnut oak seedlings were planted on a poorly drained, upland flat site following three levels of site preparation. The soil type was Avonburg-Clermont (a fine-silty mixed mesic type), and the site had been grazed prior to establishment of the study. Depth to a fragipan varied from 30 to 40 inches and seasonal water table varied from I-3 ft. The site preparation treatments were disking, disking and bedding, and control. Seed was collected within a lo-mile radius of the study site and grown for 1 year in a nursery. Seedlings were hand-planted on a 10 by 10 ft spacing. Weed control was accomplished by treating areas around each seedling with glyphosate and simazine, and mowing untreated areas within rows. After 3 years, plantation survival averaged 89% for all treatments and was not influenced by site preparation; after 5 years, survival had dropped to 83%. Survival after 5 years was 15% lower for control plots compared to the other two treatments, but the difference was not statistically significant. After 5 years, mean height was 150 cm for the control plots, 165 cm for the disked plots, and 142 cm for the disked and bedded plots. In the fifth year, both height and diameter increments were significantly greater for the disked and disked and bedded plots compared to the control plots.

Sharitz, R.R., and L.C. Lee. 1985. Limits on regeneration processes in southeastern riverine wetlands. Pages 139-143 in Riparian ecosystems and their management: reconciling conflicting uses. U.S. Forest Service General Technical Report RM-120, Fort Collins, CO.

This paper presents data from wetland regeneration studies on the Savannah River floodplain in South Carolina. Research showed that although tree seed production seemed adequate, microsite factors and water-level changes limited regeneration success. Low seed viability, especially for baldcypress, seemed to be an important limiting factor. Release of seeds for both baldcypress and water tupelo peaked in November. The recovery of marked seeds released into the floodplain environment revealed that potentially more than 50% of the seeds were retained within 500 m of the parent tree. Review of existing literature suggested that reduced carbohydrate storage may be a major factor contributing to the eventual decline of baldcypress seedlings and mature trees in thermally impacted areas (i.e., discharges of heated water from the cooling systems of nuclear reactors) of the Savannah River floodplain forest. The natural establishment, development, and maintenance of floodplain forests in the Southeast is largely dependent on the coincident availability of viable seeds coupled with low water levels during periods in the growing season when germination and seedling establishment can occur. Managed water levels have generally precluded establishment and maintenance of important tree species on the Savannah River floodplain. Additional research is needed to establish watershed management methods that will satisfy the requirements of floodplain forests.

Silker, T.H. 1948. Planting of water-tolerant trees along margins of fluctuating-level reservoirs. Iowa State College Journal of Science 22:431-447.

The results of trial plantations with eight species along the margins of Tennessee Valley Authority reservoirs in the lower Tennessee River Valley are described. Species planted were baldcypress, water tupelo, sweetgum, green ash, water oak, willow oak, Atlantic white cedar, and sycamore. The plantations were established either in the upper drawdown zone of the reservoirs (soils intermittently covered with l-3 ft of water at normal pool level) or in surcharge zones (soils 1-15 ft above normal pool level that are flooded occasionally). Some plantations were established with nursery-grown seedlings, and in other cases with transplanted wild seedlings. Five-year development of plantations of all eight species in the surcharge zone are discussed by cover and soil conditions, water-level conditions, and species. Average survival was 60% or better for all species except Atlantic white cedar; the poor survival (11%) of the latter species was attributed to the poor quality of the wild planting stock used. Height growth ranged from 3.3 ft for water tupelo to 14.3 ft for sycamore in broom sedge cover areas; most species obtained their best height growth in sites with woody cover rather than broom sedge or hydrophytic weed cover. Only baldcypress, water tupelo, and Atlantic white cedar were planted in upper drawdown areas. Survival of baldcypress and water tupelo plantations after 11 or 12 years was 88% or better. Atlantic white cedar had 58% survival after 9 years, and the largest rate of annual height growth (2.5 ft/year), followed by baldcypress (1.9 ft/year), and water tupelo (1.8 ft/year).

Stubbs, J. 1963a. Planting hardwoods on the Santee Experimental Forest. Southern Lumberman 207:135-136, 138.

Planting trials of yellow-poplar, white ash, swamp chestnut oak, Shumard oak, and cherrybark oak on the Santee Experimental Forest, near Charleston, SC, are briefly summarized. Stream bottom and terrace sites were planted, but only results from terrace sites are discussed. Soil types on the planted sites include Coxville loam and phosphatic variants of Bayboro clay loam and Chastain very fine sandy loam. The sites previously supported stands of good quality hardwoods dominated by cherrybark and Shumard oaks, yellow-poplar, sweetgum, white and swamp chestnut oaks, and white ash. Prior to planting, all merchantable wood was removed; the remaining culls were killed using 2,4,5-T, but no further site preparation was done. Planting was done during winter using a lo-inch planting bar and root-pruned l-year-old seedlings. Average survival for all species was 76% after one growing season. Survival after 5 years ranged from 46% for cherrybark oak to 81% for white ash. In two trials, planted in consecutive years, yellow-poplar had the best average height growth after 5 years (6.7 ft), and cherrybark oak had the lowest (4.6 ft). Yellow-poplar did much better on well-drained sites with deep topsoil; survival on such sites was 89% and dominant trees reached 15 ft. Cherrybark and Shumard oak showed extreme variation in individual seedling height growth, which could not be explained. Survival and growth of swamp chestnut oak were generally better than the red oaks and compared favorably with yellow-poplar on most sites.

Stubbs, J. 1963b. Survival and growth of sweetgum, Shumard oak, and spruce pine planted on a creek bottom site in the Carolina coastal plain. Journal of Forestry 61:386-388.

Results are given of a study of sweetgum, Shumard oak, and spruce pine planted in an area of cleared forest on a stream terrace (second bottom) near Charleston, SC. Plots were planted in January 1955 with graded 1-O seedlings raised from local seed. A conventional IO-inch planting bar was used. Several planting spacings were evaluated; these were 4 by 4, 6 by 6, and 8 by 8 ft. After five growing seasons, any effects of spacing were not evident. Sweetgum had 91% survival and averaged 12.5 ft in height; corresponding values for Shumard oak were 72% and 5.2 ft, and spruce pine 48% and 7.7 ft. The breaking up of dead overstory trees, which were killed by herbicide treatment after first clearing the area of all merchantable timber, caused considerable damage to the planted trees. Vines were major competitors, and when they were supported by saplings, some stem deformation occurred. Planted sweetgum exhibited vigorous growth and few individuals were overtopped by competing vegetation. Other desirable features of sweetgum that made this species particularly amenable to management include (1) production of large quantities of easily collected seed most years, (2) good seed viability, (3) easily grown nursery stock, and (4) easy planting. The authors note that without cleaning and weeding, only the sweetgum plantings resulted in well-stocked, homogeneous stands. Patches of natural sweetgum, yellow-poplar, and oak of both seedling and sprout origin often outgrew the planted trees.

Swenson, E.A., and C.L. Mullins. 1985. Revegetating riparian trees in southwestern floodplains. Pages 135-138 in Riparian ecosystems and their management: reconciling conflicting uses. U.S. Forest Service General Technical Report RM-120, Fort Collins, CO.

Managers have generally been unsuccessful in using conventional techniques to replace riparian trees, and in this paper an alternative using large cuttings is discussed. Experiments with Rio Grande cottonwood, narrowleaf cottonwood, and Goodding willow showed that placing large, dormant cuttings into holes predrilled to the depth of the growing season water table can be a simple and inexpensive method of revegetating floodplains. The cuttings were obtained from saplings with a basal diameter of 2-3 inches and a height of up to 20 ft; all side branches were removed, and the tops were cut back to a 3/8-inch diameter. Success of such plantings, however, is unlikely unless prolonged flooding does not occur at the site and beaver and livestock can be controlled.

Thompson, R.L., W.G. Vogel, G.L. Wade, and B.L. Rafaill. 1986. Development of natural and planted vegetation on surface mines in southeastern Kentucky. Pages 145-153 in New horizons for mined land reclamation. Proceedings of the American Society for Surface Mining and Reclamation, Princeton, WV.

Descriptive studies made of the flora on five 17- to 20-year-old surface-mined areas that originally had been partly or entirely planted with herbaceous and woody species are covered in this paper. A rich flora was found on these mines as a result of natural secondary succession together with the artificial plantings. Important invading species common at all or most of the sites were red maple, yellow-poplar, black locust, sourwood, blackgum, and sycamore. Changes in hydrology and rooting depth, associated with old mining practices, seemed to have created forest-site conditions that were sometimes more mesic and potentially more productive than the premining condition. Although additional studies are recommended, the data revealed that potentially productive forest ecosystems are reestablishing on some of the older surface-mined sites in southeastern Kentucky.

Toliver, J.R. 1986. Survival and growth of hardwoods planted on abandoned fields. Louisiana Agriculture 29(2):10-11.

The article reports on trials with six bottomland hardwood species that were planted on old soybean fields at Thistlethwaite Game Management Area in St. Landry Parish, LA. Two soil types, Baldwin and Dundee silty clay loams, were represented in the plantations. Both types are high in fertility, but the Baldwin soil type has a higher clay content and lower permeability. Pecan, sweetgum, sycamore, and cherrybark oak seedlings were planted on soybean stubble after harvest in February. Green ash and baldcypress were planted on disked soybean fields that had lain fallow for 2 years. All seedlings were 1-year-old bare-rooted stock that had tap roots pruned to a length of 6-8 inches, and were hand-planted on a 10 by 10 ft spacing using a planting bar. Weed control generally consisted of disking and/or mowing between trees two or three times during the growing season for the first 3 years, and an application of herbicide (Roundup) sprayed around individual trees in June or July.After the third year, the plantations were mowed at least once each year. After 5 years, sycamore survival averaged 92% and mean height averaged 13.6 ft for two plantations; cherrybark oak survival averaged 74% and height, 6.4 ft for three plantations; survival and mean height were 48% and 2.7 ft for pecan and 46% and 6.8 ft for sweetgum. After 3 years, green ash had 97% survival and a mean height of 7.9 ft on one plantation. After 2 years baldcypress had 98% survival and a mean height of 4.1 ft.

Toliver, J.R., R.C. Sparks, and T. Hansbrough. 1980. Effects of top and lateral root pruning on survival and early growth on three bottomland hardwood species. U.S. Forest Service Tree Planters' Notes 31(3):13-15.

This paper describes one- and five-year results of planting trials with five combinations of top- and/or root-pruned seedlings of water oak, willow oak, and pecan. Out-planted seedlings of all species had excellent survival (96%) after 1 year, and the differences in survival between the various treatments of root and/or top pruning were minor. Average height growth after 1 year was highest for water oak (51.0 cm), followed by willow oak (49.0 cm) and pecan (26.4 cm). By the fifth year, survival of willow oak and pecan was still greater than 90%, but water oak survival dropped to 82.4%. Willow oak had the greatest average height after 5 years (372.0 cm), followed by water oak (332.2 cm) and pecan (131.0 cm). Overall the differences were minor between the treatments, but the combination of root pruning and top pruning tended to produce the best height growth for all species and is therefore recommended.

U.S. Bureau of Land Management (BLM). 1983. Environmental assessment on state of reclamation techniques on phosphate mined lands in Florida and their application to phosphate mining in the Osceola National Forest. U.S. Bureau of Land Management, Eastern States Office, Alexandria, VA.

This assessment concludes that although there are many studies underway, there is a lack of conclusive data on the ability to reestablish wetland hardwoods on phosphate-mined land in central Florida. The assessment provides a summary of 29 wetland reestablishment studies within the Florida phosphate industry between 1975 and 1982 (most studies were less than 5-years-old).

Vogel, W.G. 1973. The effect of herbaceous vegetation on survival and growth of trees planted on coal-mined spoils. Pages 197-207 in Proceedings of the research and applied technology symposium on mined-land reclamation. Bituminous Coal Research, Inc., Monroeville, PA.

This study examines the effects of herbaceous competition with trees on coal-mine spoils in southeastern Kentucky. Grass alone and grass with legumes were sown concurrently with the planting of trees. After three growing seasons, the herbaceous vegetation, which covered about 95% of the ground, did not significantly affect survival of the trees but greatly suppressed their growth. During the fourth and fifth growing seasons, the growth of trees in plots dominated by legumes exceeded growth in the other treatment plots. Tree growth was suppressed most by grass cover alone.

Vogel, W.G. 1980. Revegetating surface-mined lands with herbaceous and woody species together. Pages 117-126 in Proceedings of trees for reclamation. U.S. Forest Service General Technical Report NE-61, Broomall, PA.

The report covers tests with trees (cottonwood, sycamore, pines) planted with herbaceous species. Results showed there was an increase in tree seedling mortality and retarded tree growth, especially in the first few years after planting. The trees seemed to be most affected by competition for moisture; survival was least affected where spring and summer precipitation was abundant. In some areas, tree survival was reduced by dense stands of some legumes, such as crown vetch, flat pea, and sericea lespedeza. Planting trees in existing stands of herbaceous cover usually resulted in poor survival. Herbicides or scalping to control competition was suggested, although it was noted that there was little supporting data. Planting trees and seeding herbaceous species in alternate strips was believed to be a feasible method.

Vogel, W.G. 1981. A guide for revegetating coal mine soils in the eastern United States. U.S. Forest Service General Technical Report NE-68, Broomall, PA. 190 pp.

This technical report provides information, recommendations, and guidelines for revegetating land in the eastern United States that has been disturbed by coal mining. The document includes information on a variety of tree species associated with bottomland forest sites, as well as guidance on grading and leveling, seeding practices, planting methods, soil amendments, mulches, soil stabilizers, and erosion control.

Wadsworth, C.A. 1983. The development of techniques for the use of trees in the reclamation of phosphate lands--a project overview. Pages 390-394 in D.J. Robertson, ed. Reclamation and the phosphate industry. Proceedings of Symposium; 26-28 January, 1983; Clearwater Beach, FL. Florida Institute of Phosphate Research, Bartow, FL.

In this project, thirteen research plots, involving 30 species (e.g., laurel oak, sycamore, cottonwood, baldcypress) were planted during 1981. The three main objectives of the project were (1) establish and monitor trial plantings of the most promising tree species on a variety of representative phosphate soils, (2) develop techniques for the direct seeding of sand pine and slash pine on tailing sands, and (3) develop criteria and guidelines for the use of trees to recreate wetland, island, upland, and aquatic habitat on mined wastes. Initial survival for the various species was reported, but since the data were only for about one growing season, no conclusions on the success of the project could be drawn.

Waldrop, T.A., E.R. Buckner, and A.E. Houston. 1983. Suitable trees for the bottomlands of west Tennessee. Pages 157-160 in Proceedings of the second biennial southern silvicultural research conference. U.S. Forest Service General Technical Report SE-24, New Orleans, LA.

This study examines three species: sweetgum, green ash, and sycamore; two seed sources for sweetgum and sycamore; and three cultural treatments (fertilization, disking, and mowing) to determine which combination(s) would be best suited to abandoned agricultural fields. The study site was on the floodplain of a tributary to the Wolf River in southwest Tennessee. The fields were farmed for soybeans until 1979; flooding occurred less than annually, but enough to make soybean planting risky. The soils were silt loam, 5.4-6.6 pH, and lower in phosphorus and potassium than most soils used for agricultural purposes. Seedlings were planted in the spring of 1980. Five species/seed source combinations (sycamore, green ash, sweetgum from the Virginia coastal plain, and sweetgum and sycamore from the Louisiana gulf coast) were tested, with fertilization as the main treatment. Disking and mowing were tested at the subplot level. After three growing seasons, survival was over 90% for all treatments, and there were no significant survival differences among the five species/seed source combinations. Survival was slightly lower in the fertilized plots (93% versus 95%), perhaps due to the exceptionally dry season following planting and fertilization in 1980. Seed source did not significantly affect height growth after three growing seasons. Sycamore grew the fastest (mean height of 9.0 ft after three growing seasons), followed by green ash (6.1 ft) and sweetgum (5.4 ft). Fertilization increased the height growth of green ash by 25%, sycamore, 19%, and sweetgum, 16%. Disking improved growth significantly over mowing for all species. Response was greatest for sycamore (52%), followed by green ash (50%) and sweetgum (26%). Disking and fertilization both increased growth when applied alone, but combining the two did not produce a significant growth advantage, especially for sycamore.

Walker, L.C., and K.G. Watterston. 1972. Silviculture of southern bottomland hardwoods. School of Forestry Bulletin 25. Stephen F. Austin University, Nacogdoches, TX. 79 pp.

This handbook covers bottomland hardwood silviculture in the Mississippi River Delta, Coastal Plain Alluvial Valley, and Piedmont Alluvial Valley regions. Each of the three regions is briefly described in the first section, with the Mississippi River Delta Region covered in greatest detail. The next section contains a general description of injurious agents in southern bottomland hardwood forests, including decay caused by fire, beaver damage and increment coring, insects, grazing, competition, windthrow, and flooding effects. A useful key to some of the more important types of insect damage is provided in this section. The final section covers the silviculture of selected species or species groups, including cottonwood, blackwillow, oaks, sweetgum, water tupelo, sycamore, and yellow-poplar. The species subsections vary considerably in depth of treatment, but typically cover growth, site index and/or vigor, and means of regeneration. The handbook contains 119 references, which should be of considerable use to individuals needing more information on a particular species or injurious agent.

Wenger, K.F., editor. 1984. Forestry handbook (2nd edition). John Wiley and Sons, New York. 1,335 pp.

This is a major reference book of data and methods in all phases of forestry and allied fields directed primarily at the practicing field forester. For those interested in forest reestablishment, sections on forest insect and disease management, fire management, and silviculture should be of interest. The section on silviculture includes information on stand regeneration, site preparation and management of problem vegetation (including a herbicide selection guide), and managing for natural regeneration.

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Appendix A. Common and scientific names for some bottomland forest species (from Clark and Benforado 1981).

Common name	Scientific name
Carolina ash	Fraxinus caroliniana
Pumpkin ash	F. profunda
Green ash	F. pennsvlvanica
White ash	F. americana
American beech	Fagus grandifolia
River birch	Betula niqra
Buttonbush	Cephalanthus occidentalis
Black cherry	Prunus serotina
Eastern cottonwood	Populus deltoides
Swamp cottonwood	P. heterophylla
Baldcypress	Taxodium distichum
Pondcypress	T. distichum var. ~~nutans~~
Flowering dogwood	Cornus florida
Rough-leaf dogwood	C. drummondii
American elm	Ulmus americana
Cedar elm	U. crassifolia
Slippery elm	U. rubra
Winged elm	U. alata
Water-elm	Planera aauatica
Sweetgum	Liauidambar stvraciflua
Blackgum	Nyssa sylvatica
Ogeechee tupelo	N. oqeche
Swamp tupelo	N. svlvatica var. biflora
Water tupelo	N. aauatica
Hackberry	Celtis occidentalis
Sugarberry	C. laevioata
Hawthorn	Crataequs spp.
Water hickory	Carva aauatica
Shellbark hickory	C. laciniosa
Shagbark hickory	C. ovata
Pecan	C. illinoensis
American holly	Ilex opaca
Possumhaw	I. decidua
Eastern hophornbeam	Ostrva virqiniana
American hornbeam	Carpinus caroliniana
Honeylocust	Gleditsia triacanthos
Waterlocust	G. aauatica
Loblolly-bay	Gordonia lasianthus
Redbay	Persea borbonia
Southern magnolia	Maqnolia srandiflora
Swampbay	Persea borbonia var. pubescens
Sweetbay	Masnolia viroiniana

(Continued)

Appendix A. (Concluded).

Common name	Scientific name
Boxelder	<u>Acer nectundo</u>
Florida maple	<u>A.</u> <u>barbatum</u>
Red maple	<u>A.</u> <u>rubrum</u>
Silver maple	<u>A.</u> <u>saccharinurn</u>
Red mulberry	<u>Morus rubra</u>
Bur oak	<u>Quercus macrocarpa</u>
Cherrybark oak	<u>Q.</u> <u>falcata</u> var. Daqodifolia
Delta post oak	<u>Q.</u> <u>stellata</u> var. <u>paludosa</u>
Laurel oak	<u>Q.</u> <u>laurifolia</u>
Live oak	<u>Q.</u> <u>viroiniana</u>
Nuttall oak	<u>Q.</u> <u>nuttallii</u>
Overcup oak	<u>Q.</u> <u>lyrata</u>
Pin oak	<u>Q.</u> <u>palustris</u>
Shumard oak	<u>Q.</u> <u>shumardii</u>
Swamp chestnut oak	<u>Q.</u> <u>michauxii</u>
Water oak	<u>Q.</u> <u>nigra</u>
White oak	<u>Q.</u> <u>alba</u>
Swamp white oak	<u>Q.</u> <u>bicolor</u>
Willow oak	<u>Q.</u> <u>phellos</u>
Pawpaw	<u>Asimina triloba</u>
Common persimmon	<u>Diosovros viroiniana</u>
Sassafras	<u>Sassafras albidum</u>
American sycamore	<u>Plantanus occidentalis</u>
Swamp-privet	<u>Forestiera acuminata</u>
Black walnut	<u>Juolans</u> <u>nisra</u>
Black willow	<u>Salix nigra</u>
Sandbar willow	<u>S. exiqua</u>
Yellow-poplar	<u>Liriodendron tulipifera</u>

Appendix B. Table of flooding and shade tolerance and reproductive characteristics of some bottomland forest species (from Fowells 1965; McKnight et al. 1981).

KEY TO FLOOD TOLERANCE

T (tolerant)--Species are able to survive and grow on sites where soil is saturated or flooded for long periods during the growing season. Species have special adaptations for flood tolerance.

MT (moderately tolerant)--Species are able to survive saturated or flooded soils for several months during the growing season but mortality is high if flooding persists or reoccurs for several consecutive years. These species may develop some adaptations for flood tolerance.

WT (weakly tolerant)--Species are able to survive saturated or flooded soils for relatively short periods of a few days to a few weeks during the growing season; mortality is high if flooding persists longer. Species do not appear to have special adaptations for flood tolerance.

I (intolerant)--Species are not able to survive even short periods of soil saturation or flooding during the growing season. Species do not show special adaptations for flood tolerance.

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Carolina ash	T--Seeds remain viable in water for months.	Intermediate. Seedlings moderately tolerant.	Seeds dispersed Oct.-Feb. by wind and water. Seedlings establish on bare, moist soil after water recedes. Sprouts well from stumps.
Pumpkin ash	Same as for Carolina ash.	Same as for Carolina ash.	Same as for Carolina ash.
Green ash	MT	Same as for Carolina ash.	Seeds dispersed from fall to early spring primarily by wind and to some extent by water. Germination on bare, moist soil in openings. Sprouts prolifically. Excellent seed dispersal.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
White ash	WT	Same as for Carolina ash.	Seeds dispersed Sept.-Jan. primarily by wind. Seedlings establish best on bare, moist, well-drained soils. Sprouts prolifically from stumps.
American beech	I	Very tolerant	Seedfall Sept.-Dec. by gravity and animals to some extent. Trees about 40 years of age (optimum 60 years) bear seed. Dispersal usually limited to crown area. Seedlings establish best in shade on moist, well-drained soils. Sprouts well from roots and stumps.
River birch	MT	Intolerant	Seeds dispersed May-June by wind and water. Trees bear seed at about 40 years of age. Seedlings establish on moist, well-drained soils. Rapid early growth from seed.
Buttonbush		Tolerant	Seeds dispersed Oct.-Nov. by wind and water. Very moist seedbed is optimum. Stumps of all sizes sprout.
Black cherry		Intermediate	Seeds dispersed Aug.-Nov. Birds and animals may move seeds long distances. Trees from about 10 to 180 years of age bear seed. Seeds establish in bare mineral soil or in leaf litter. Sprouts from stumps.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Eastern cottonwood	WT-MT	Very intolerant	Seeds dispersed May-Aug. largely by wind and water. Trees as early as 10 years of age (optimum 30-40 years) bear seed. Seeds may remain viable for less then 2 weeks. Germination best on moist mineral soil. Sprouts well from stumps. up to 12 inches.
Swamp cottonwood	MT	Intermediate	Seeds dispersed April-July largely by wind and somewhat by water. Trees about 10 years of age bear seed. Seeds short-lived. Germination best on bare, moist, mineral soil. Rapid early growth. Sprouts well from stumps up to 12 inches.
Baldcypress	T--seeds stay viable in water up to 30 months Prolonged submergence of seedlings is fatal.	Intermediate	Seeds dispersed Nov.-Feb. primarily by water. Seedlings established when water recedes. Sprouting inconsistent from stumps up to 20 inches.
Pondcypress	T	Intermediate	Similar to baldcypress.
Flowering dogwood	I	Very tolerant	Seeds dispersed Nov. by gravity, animals, and birds. Germination best on bare mineral soil in understory or openings. Stumps of all sizes sprout well.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Rough-leaf dogwood	T	Tolerant	Seeds dispersed in fall by gravity, animals, and birds. Seedlings establish best on moist soil under partial shade. Sprouts well from stumps.
American elm	MT-Seeds remain viable when submerged for a month.	Tolerant	Seeds dispersed March-June by wind and water. Trees as early as 15 years of age bear seed. Seeds germinate and seedlings establish on surface of moist mineral soil or on undisturbed humus. Stumps up to 15 inches sprout well.
Cedar elm	MT	Tolerant	Seeds dispersed Oct.-Nov. largely by wind and water. Seedlings established in shade or in openings on moist, bare mineral soil. Stumps up to 12 inches sprout well.
Slippery elm	I	Tolerant	Seeds dispersed April-June largely by wind and less by water. Trees as early as 15 years of age, (optimum 25-125 years) bear seed. Seedlings established in shade or in openings on moist, usually well-drained soil. Stumps up to 12 inches sprout well.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Winged elm	WT-I	Tolerant	Seeds dispersed in April by wind and water. Seedlings largely in new openings. Stumps to 12 inches sprout well.
Water elm		Tolerant	Seeds dispersed in April. Seedlings established after water recedes. Sprouts well from stumps.
Sweetgum	MT	Intolerant--cannot stand over-topping.	Seeds dispersed in fall primarily by wind. Trees about 20 years of age, continuing to 150 or more years, bear seed. Prolific seeder. Germination best on mineral soil in open. Sprouts well from roots and stumps.
Blackgum	WT	Intermediate	Seeds dispersed Sept.-Nov. by water and to some extent by animals. Germination and establishment only on dry soil. Stumps to 12 inches sprout well.
Ogeechee tupelo	T--Seeds can survive in water for several months.	Intolerant	Seeds dispersed Oct.-Nov. Birds and animals may move some seed. Seedlings produced when water recedes.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Swamp tupelo	T--Seeds remain viable for months in water	Intermediate--does not tolerate overtopping. Responds to release.	Seeds dispersed primarily by birds and somewhat by water. Trees bear seed at about 30 years of age. Usually good-to-excellent seed crop. Germinates best in partial shade on moist seedbed. Sprouts from stumps and sprouts produce viable seeds in second year.
Water tupelo	T--Seeds remain viable for months in water.	Intolerant	Seeds dispersed by water and animals. Trees beginning about 30 years of age bear seed. Usually good-to-excellent seed crop. Needs full sunlight for germination. Stump sprouts produce viable seeds in second year.
Hackberry and Sugarberry	MT--Seeds remain viable for months in water; seedlings cannot tolerate submergence.	Very tolerant	Seeds dispersed Oct.-Jan. by birds, animals, and water. Trees at about 15 years of age (optimum 30-70 years) bear seed. Seedlings often in full shade. Sprouts well from stumps to 12 inches.
Hawthorn	MT	Intermediate to intolerant	Seeds dispersed fall and winter. Does not readily establish seedlings. Trees are good sprouters.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Water hickory	MT--Seeds remain viable in water for several months.	Intermediate	Seeds dispersed Oct.-Dec. by gravity, water, animals, and birds. Trees at about 20 years of age (optimum 40-75 years) bear seed. Seedlings more common in new openings but also occur in understory. Sprouts well from stumps to 20 inches.
Shellbark hickory	WT	Very tolerant	Seeds dispersed Oct.-Dec. by gravity, animals, and birds. Trees at about 40 years of age (optimum 75-200 years) bear seed. Germination and establishment in understory and openings. Moist soils are required for seedling establishment. Sprouts well from stumps.
Shagbark hickory	WT	Moderately tolerant	Seeds dispersed Sept.-Dec. by gravity and animals. Trees at 40 years of age (optimum 60-200 years) bear seed. Seedlings require moderately moist seedbed. Sprouts well from stumps.
Pecan	WT	Intolerant	Seeds dispersed Sept.-Dec. by birds and animals. Trees at about 20 years of age (optimum 75-225 years) bear seed. Seedlings establish best in an inch or so under loamy soil. Sprouts well from stumps to 12 inches.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
American holly	WT	Very tolerant	Seeds dispersed Nov.-March by birds and animals. Seedlings occur in understory and openings. Sprouts well from stumps.
Possumhaw	MT	Very tolerant	Seeds dispersed Sept.-March. Seedlings become established in shade and openings. Sprouts well from stumps.
Eastern hophornbeam	I	Very tolerant	Seeds dispersed in fall. Seedlings establish well in understory and new openings. Moist mineral soil is best seedbed. Sprouts well from stumps of all sizes.
American hornbeam	MT	Very tolerant	Seeds dispersed fall to spring largely by birds and short distances by wind. Similar to Eastern hophornbeam.
Honeylocust	MT	Intolerant	Seeds dispersed Sept.-Feb. by wind, birds, animals, and sometimes water. Trees at about 10 years of age (optimum 25-75 years) bear seed. New seedlings seldom in understory, but in openings. Sprouts well from stumps.
Waterlocust	MT	Intolerant	Similar to honeylocust.
Loblolly-bay	MT	Intermediate	Seeds dispersed in fall.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Redbay	MT	Tolerant	Seeds dispersed in fall to some extent by birds. Germinates in both understory and openings. Fire stimulates germination. Sprouts well from stumps.
Southern magnolia	WT	Tolerant	Seeds dispersed Sept.-Dec. by birds and other animals. Trees as early as 10 years of age bear seed. Usually good seed crop, but low germination. Good stump sprouter.
Swamp bay	MT	Tolerant	Seeds dispersed in fall by birds. Seedlings establish both in understory and openings. Good stump sprouter.
Sweetbay	MT	Moderately tolerant	Seeds dispersed Sept.-Nov. by birds and small animals. Seedlings establish both in shade and openings.
Boxelder	MT	Moderately tolerant	Seeds dispersed Sept.-March by wind, birds, and small animals. Germinates best on moist mineral soil in shade or openings. Sprouts well from stumps.
Florida maple	WT	Tolerant	Seeds dispersed Oct.-Dec. by wind, birds, and small animals. Germinates best on moist mineral soil in shade or openings. Sprouts well from stumps.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Red maple	MT	Tolerant	Seeds dispersed March-July primarily by winds, and to some extent, by water, birds, and small animals. Germinates best on moist mineral soil in shade or openings, often after water recedes. Sprouts well from stumps.
Silver maple	MT	Moderately tolerant to intolerant	Seeds dispersed April-June by wind, water, birds, and small animals. Trees about 35-40 years of age (or sooner if grown in the open) bear seed. Seedlings occur in shade or openings. Sprouts well from stumps.
Red mulberry	WT-I	Very tolerant	Seeds dispersed June-Aug. by birds and other animals. Seedlings occur in shade or openings. Sprouts well from stumps.
Bur oak		Intermediate	Seeds dispersed Aug.-Nov. mainly by gravity and squirrels, and to a limited extent by water. Trees at about 35 years of age (optimum 75-150 years) bear seed. Germination may be prolific in bottomland areas; seedlings are often killed if flooded during the growing season. Sprouts well from stumps and following burning of small trees although the quality and form of sprout stems often poor.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Cherrybark oak	WT-I	Moderately intolerant to intolerant	Seed dispersed Aug.-Nov. by gravity, birds, and animals; seldom by water. Trees seed at about 25 years of age (optimum 50-75 years). Not a good stump sprouter.
Delta post oak	WT-I	Intermediate	Seeds dispersed in fall by gravity, birds, animals, and sometimes water. Trees bear seed at about 25 years of age. Seedlings most common in openings. Not a good stump sprouter.
Laurel oak	MT-WT	Intermediate to tolerant	Seeds dispersed Sept.-Dec. by gravity, birds, animals, and sometimes water. Trees begin to bear seed at about 15-20 years of age. Seedlings in shade or openings. Sprouts when cut or burned.
Live oak	WT-T	Intolerant	Seeds dispersed Sept.-Nov. by gravity, birds, and animals. Germinates best in moist warm soil. Sprouts well from roots.
Nuttall oak	MT--acorns remain viable in water for at least 34 days. Seedlings killed by flooding during growing season.	Intolerant	Seeds dispersed Sept.-Feb. by animals and water. Germination best in moist soil covered with leaf litter. Trees may bear seed as early as 5 years of age. Seedlings establish in shade. Stumps of young trees sprout readily.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Overcup oak	MT--Seedlings among most tolerant of the oaks, but may be killed by high water during first growing seasons.	Moderately intolerant	Seeds dispersed Sept.-Nov. by birds, animals, and water. Trees bear seed at about 25 years of age. Acorns viable after 4 months in water. Germination best on moist mineral soil. Sprouting from small stumps only.
Pin oak	MT--Seedlings among most tolerant of the oaks.	Intolerant	Seeds dispersed Sept.-Dec. by birds and small animals, gravity, and to some extent by water and wind. Trees bear seed between ages of 25 and 80 years, although trees in openings often produce seed by 15 years. Seedlings become established in under-story openings, but many seedlings killed by flooding during growing season. Sprouts well from stumps of small trees.
Shumard oak	WT	Intolerant	Seeds dispersed Sept.-Dec. by gravity and animals; seldom by water. Trees bear seed at about 25 years of age (optimum at 50 years). Seedling establishment best in openings. Sprouting best from stumps of young trees; a poor sprouter overall.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Swamp chestnut oak	WT--Seedlings are intolerant to flooding.	Moderately tolerant	Seeds dispersed Sept.-Oct. by gravity and animals. Seed bearing begins about 25 years of age (optimum at about 40 years). Germination best on moist, well-drained soils with a light cover of leaves. Seedlings require full sunlight for best development. Sprouts from small stumps.
Water oak	WT-MT--Prolonged submergence of seedlings during growing season is fatal.	Intolerant	Seeds dispersed Sept.-Nov. by gravity, birds, animals, and water. Seed production begins at about 20 years of age. Seedlings establish best on moist, well-aerated soil under light leaf litter. Sprouts readily from young stumps.
White oak	I-WT--Seedlings intolerant.	Intermediate	Seeds dispersed Sept.-Nov. by gravity and squirrels. Seed bearing normally between 50 and 200 years for open-grown trees. Germination best on moist, well-drained soil. Sprouts well from stumps and following fire damage.
Swamp white oak	MT	Intermediate	Seeds dispersed primarily by gravity, rodents, and water. Trees about 35 years of age (optimum 75-200 years) bear seed. Sprouts from stumps.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Willow oak	WT-MT--Prolonged flooding during growing season is fatal.	Intolerant	Seeds dispersed Oct.-Dec. by gravity, animals and water. Trees bear seed at about 20 years of age. Germination best on moist, well-aerated soil with light leaf litter. Sprouts from young stumps.
Pawpaw		Very tolerant	Seeds dispersed Aug.-Oct. by gravity, birds, and small animals. Seedlings establish in shade and openings. Sprouts well from stumps.
Persimmon	MT--Prolonged flooding or submergence by water during growing season will kill young trees.	Tolerant	Seeds dispersed Oct.-Dec. by animals and birds. Trees bear seed as early as 10 years of age (optimum 25-50 years). Seedlings establish in understory and openings. Sprouts readily from stumps and roots.
Sassafras		Intolerant	Seeds dispersed Sept.-Oct. by gravity and birds. Trees about 10 years of age (optimum 25-50 years) bear seed. Germination best on moist loamy soil with litter. Grows well in openings. Sprouts well from roots and stumps.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Sycamore	MT--Seeds remain viable in water for 1 month. Seedlings cannot tolerate prolonged flooding.	Moderately tolerant	Seeds dispersed Jan.-April by wind, water, and birds to some extent. Trees 25 years of age (optimum 50-200 years) bear seed. Seedlings establish best on moist mudflats or other exposed mineral soil. Sprouts well from stumps.
Swamp-privet	T--Viability of seed not reduced by prolonged submergence in water.	Tolerant	Seeds dispersed June-July by water and birds. Germination best in moist mineral soil. Sprouts well from stumps.
Black walnut	WT--Seedlings intolerant.	Intolerant	Seeds dispersed Oct.-Nov. by gravity and animals. Trees may bear seed at 8 years of age (optimum 30-100 years). Seedlings mainly in forest openings. Small stumps sprout well.
Black willow	T--Seeds will germinate in water.	Very intolerant	Seeds dispersed April-July by wind and water. Trees about IO years of age (optimum 25-75 years) bear seed. Germination best on very moist, exposed mineral soil. Sprouts well from stumps of small trees.
Sandbar willow	MT--Seedlings tolerate well.	Very intolerant	Seeds dispersed April-May by wind and water. Similar to Black willow.

(Continued)

Appendix B. (Continued).

Common name	Flood tolerance	Shade tolerance	Reproductive characteristics
Yellow-poplar	I--Seedlings cannot tolerate flooding.	Intolerant	Seeds dispersed Oct.-March by wind. Trees bear seed at about 15-20 years of age and continue to 200 years or more. Seedlings establish best on moist seedbeds of mineral soil and survive only in full sunlight. Sprouts readily from stumps.

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Baker and Broadfoot 1979
Bonner 1984
Briscoe 1957
Briscoe 1961
Haynes and Moore 1987
Hosner 1959
Hosner and Boyce 1962
Johnson 1979
Kennedy 1984
Kennedy and Krinard 1985
Kennedy et al. 1986
Lotti 1959
Nelson 1957
Stubbs 1963a
Toliver 1986

Oak, chestnut
Philo 1982
Richards et al. 1982

Oak, laurel
Briscoe 1957
Erwin et al. 1985
Haynes and Crabill 1984
Klawitter 1963

Kennedy et al. 1986
Krinard and Johnson 1981
Krinard and Kennedy 1981
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Limstrom 1960
Malac and Heeren 1979
McDermott 1954
Nawrot and Yaich 1983
Nelson 1957
Raisanen 1982
Silker 1948
Thompson et al. 1986
Toliver 1986
Vogel 1980
Wadsworth 1983
Waldrop et al. 1983
Walker and Watterston 1972

Tupelo, swamp
Briscoe 1957
DuBarry 1963
Klawitter 1963
Maki et al. 1980

Tupelo, water
Baker 1977
Bonner 1964
Bonner 1977
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Dickson and Broyer 1972
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Sharitz and Lee 1985
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Tupelos
Leitman et al. 1983

Walnut, black
Anderson et al. 1983
Ashby et al. 1980
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Raisanen 1982
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Willow, (black)
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SUBJECT INDEX

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This bibliography was prepared to assist environmental planners, managers, and others who are interested in reestablishing bottomland hardwood forests on disturbed sites. Emphasis is on the Southeastern United States. There are 111 annotated entries; 259 non-annotated entries; and two appendixes--(A) common and scientific names and (B) flooding and shade tolerances and reproductive characteristics of common bottomland hardwood forest species. Cross-referencing is by species and subject.

17. Document Analysis a. Descriptors

Forests	Reforestation
Wetlands	Ecological restoration and creation

b. Identifiers/Open-Ended Terms

Bottomland hardwoods	Surface mine reclamation
Phosphate mine reclamation	Old field reforestation
Artificial regeneration	Direct seeding

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